(4)

(E84-10)84) L BAND PUSH BROOM MICRONAVE RADIOMETER: SOIL MOISTURE VERIFICATION AND TIME SERIES EXPERIMENT DELMARVA PENINSULA (NASA) 76 p BC A05/EF A01 CSCL 08M

N84-19955

Unclas G3/43 00084

NASA

Technical Memorandum 86068

! Band Push Broom Microwave Radiometer—Soil Moisture Verification and Time Series Experiment Delmarva Peninsula: Data Report

T. J. Jackson, J. Shuie, P. O'Neill, J. Wang, J. Fuchs, M. Owe

FEBRUARY 1984

National Aeronautics and Space Administration

Goddard Space Flight Center Greenbelt, Maryland 20771



4)"

L BAND PUSH BROOM MICROWAVE RADIOMETER - SOIL MOISTURE

VERIFICATION AND TIME SERIES EXPERIMENT

DELMARVA PENINSULA: DATA REPORT

T. J. Jackson 1 , J. Shiue 2 , P. O'Neill 2 , J. Wang 2 J. Fuchs 2 , M. Owe 2

February, 1984

"Made available under NASA sponsorship in the interest of early and wide dissemination of Earth Resources Survey Program inform ton and without liability for any use made thereof."

- 1/ USDA/ARS/Hydrology Laboratory, Beltsville Agricultural Research Center, Beltsville, MD $\,\,20705$
- 2/ NASA/Goddard Space Flight Center, Greenbelt, MD 20771

J'

L BAND PUSH BROOM MICROWAVE RADIOMETER - SOIL MOISTURE

VERIFICATION AND TIME SERIES EXPERIMENT

DELMARVA PENINSULA: DATA REPORT

T. J. Jackson, J. Shiue, P. O'Neill, J. Wang J. Fuchs, M. Owe

ABSTRACT

In May and June, 1983, NASA and USDA cooperated in the verification of a multi-sensor aircraft system developed to study soil moisture applications. This system consisted of a three beam push broom L band microwave radiometer, a thermal infrared scanner, a multispectral scanner, video and photographic cameras and an onboard navigational instrument. Ten flights were made of agricultural sites in Maryland and Delaware with little or no vegetation cover. Comparisons of aircraft and ground measurements showed that the system was reliable and consistent. Time series analysis of microwave and evaporation data showed a strong similarity that indicates a potential direction for future research.

KEYWORDS: Soil Moisture, Remote Sensing, Microwaves, Hydrology

PRECEDING PAGE BLANK NOT FILMED

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	SITE DESCRIPTIONS	2
3.	GROUND TRUTH ACQUISTION AND PROCESSING	5
	3.1 Soil Moisture	5
	3.2 Bulk Density	9
	3.3 Soil Texture	10
	3.4 Moisture-Tension Relationships	12
	3.5 Soil and Surface Temperatures	14
	3.6 Cover Conditions	14
4.	CLIMATOLOGICAL DATA	21
5.	AIRCRAFT AND SENSOR SYSTEMS	24
	5.1 Microwave Radiometer	24
	5.2 Heat Capacity Mapping Radiometer	27
	5.3 Ocean Color Scanner	27
	5.4 Data Processing and Calibration	31
6.	RESULTS AND DISCUSSION	32
7.	SUMMARY	50
8.	ACKNOWLE DGEMENTS	53
9.	REFERENCES	53
APP	ENDIX I - Aircraft and Ground Measurements	55
APP	ENDIX II - Climatological Observations	69

CRECEDING PAGE BLANK NOT FILMED

LIST OF FIGURES

			Page
Figure	1.	Delmarva study area	3
Figure	2.	Maryland flightlines and fi lds	4
Figure	3.	Delaware flightline 4 and fields	6
Figure	4.	Delaware flightline 5 and fields	7
Figure	5.	Laboratory moisture-tension relationships	
		for selected Delmarva fields	13
Figure	6.	Ground cover conditions on March 14, 1983,	
		Delmarva sites	15
Figure	7.	Tilled corn field (field 1) on June 2, 1983	16
Figure	8.	Corn field with soybean stubble (field 9)	
		on June 2, 1983	16
Figure	9.	Condition of a weed covered field (field 10)	
		on June 2, 1983	18
Figure	10.	Cumulative evaporation pan readings at the	
		Wye Institute May and June, 1983	22
Figure	11.	Ground cover and specifications for the	
		push broom microwave radiometer	26
Figure	12.	HCMR detector response for channel 1	28
Figure	13.	HCMR spectral response, infrared channel	29
Figure	14.	Spectral response of the 12 ocean color	
		scanner channels	30
Figure	15.	Brightness temperature vs soil moisture,	
		field 1, center beam	33
Figure	16.	Brightness temperature vs soil moisture,	
		field 13, center beam	35

LIST OF FIGURES (CONTINUED)

			Page
Figure	17.	Brightness temperature vs soil moisture,	
		field 3, center beam	36
Figure	18.	Brightness temperature vs soil moisture,	
		field 10, center beam	37
Figure	19.	Brightness temperature vs soil moisture,	
		field 5, center beam	39
Figure	20.	Brightness temperature vs soil moisture,	
		field 23, center beam	41
Figure	21.	Brightness temperature vs soil moisture,	
		field 19, center beam	42
Figure	22.	Brightness temperature vs soil moisture,	
		field 1, side beams	43
Figure	23.	Brightness temperature vs soil moisture,	
		field 19, side beams	45
Figure	24.	Brightness temperature vs Julian day and	
		cumulative evaporation pan values, field 1,	
		center beam	47
Figure	25.	Brightness temperature vs Julian day,	
		field 3, center beam	48
Figure	26.	Brightness temperature vs Julian day,	
		field 5, center beam	49
Figure	27.	Brightness temperature vs Julian day,	
		field 27, center beam	51
Figure	28.	Brightness temperature vs Julian day,	
		field 15, center beam	52

LIST OF TABLES

		Page
Table 1.	Field soil properties	11
Table 2.	Crop type codes	19
Table 3.	Tillage condition codes	19
Table 4.	Surface roughness codes	19
Table 5.	Row direction codes	19
Table 6.	Corn biomass sample data	20
Table 7.	L band radiometer specifications	25
Table 8.	Center wavelengths of the OCS II	31
Table 9.	Brightness temperature and 0-5 cm soil	
	moisture linear regression results	38

CANDED AND METAL SOFT THATED

1

1. INTRODUCTION

A principal goal of the soil moisture remote sensing research is the evaluation and development of remote sensing technology for measuring and/or monitoring soil moisture. A secondary goal is to improve existing water management procedures through the use of this technology. In some cases, the adaptation of existing procedures is necessary because conventional soil moisture surveys are impractical and, therefore, the current water management procedures have developed under the assumption that this type of data could not be obtained.

Truck and modeling experiments focus on the problems of defining optimal sensor systems and developing soil moisture estimation algorithms based on remotely sensed data. These studies allow evaluation of factors such as vegetation and soil type under well controlled conditions.

Achieving the two primary goals of the project hinges on extrapolating these experiments to airborne systems, which are prototypes of future operational systems. Significant research questions, such as the effects of scene heterogeneity and instrument sensitivity at lower resolutions, can only be addressed using airborne sensors.

Applications related objectives depend upon frequent large area coverage and rapid data turnaround. A dedicated airborne system was crucial to this line of research.

Based on these considerations, NASA and USDA cooperated in the development of an optimal sensor aircraft system that would be available for extended-dedicated periods. It includes a multibeam L band microwave radiometer, a scanning thermal infrared system, and a multispectral scanner. All systems will be time and space registered and ultimately linked to an automatic geographic referencing system.

In 1983, this aircraft sensor system was assembled. The primary purpose of the study described in this report was to verify the performance of the system. Therefore, a fairly intensive ground sampling effort was included. A secondary objective was to evaluate the potential of repetitive observation, i.e., time series, in soil moisture and climate studies.

Two agricultural test sites on the Delmarva Peninsula were selected for study due to their proximity to the research team and to the aircraft staging area. One check flight was conducted over the flightlines located in Maryland on March 14, 1983. Ten additional flights were made over the Maryland site from May 12 to June 27, 1983. Eight flights were conducted over the Delaware site during the same period.

2. SITE DESCRIPTIONS

A total of five flightlines were investigated, three near Carmichael, Maryland, and two in Kent County, Delaware. All of the sites are on the Delmarva Peninsula as shown in Figure 1.

Maryland flightlines 1, 2, and 3 were located on or near the facilities of the Wye Research Center operated by the University of Maryland's Agricultural Experiment Station. Figure 2 is a black and white photograph of the area obtained on May 24, 1983, showing the field boundaries and flightlines. With the exception of March 14, 1983, all Maryland flightlines were flown west to east. Flightlines were flown at an altitude of 150 meters (500 feet) and line 2 was also flown at 300 meters (1000 feet).

ORIGINAL PAGE IS OF POOR QUALITY

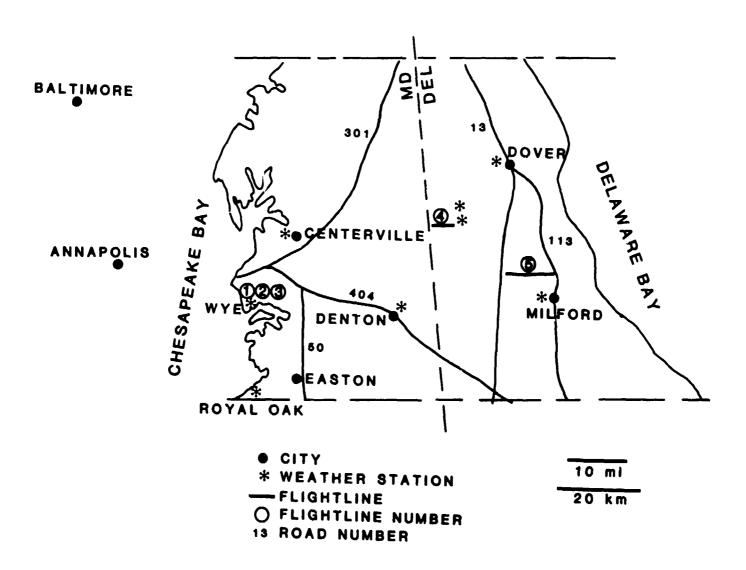
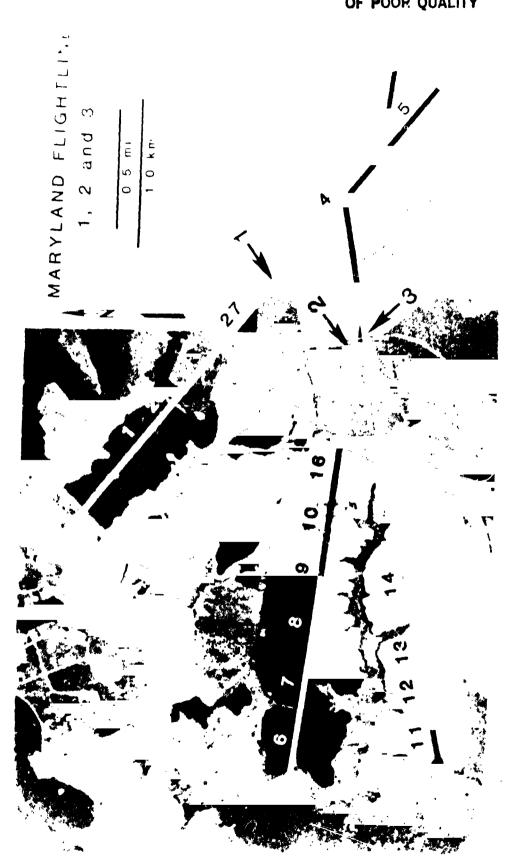


Figure 1. Delmarva study area.

ORIGINAL PAGE IS OF POOR QUALITY



igure 2. Maryland flightlines and fields.

2



In March, all of the fields had corn or soybean stubble and/or weeds.

During May and June a variety of bare soil conditions were present. Most of the fields were planted in corn, although, the tillage and mulch cover varied. Soils over this area were mostly silt loams. Additional details are presented in later sections.

Flightline 4 was located near Sandtown, Delaware and was flown in bot' directions (east to west and west to east) at 500 and 1000 foot altitudes. Field boundaries are shown in Figure 3. These fields included a variety of cover conditions over sandy loam soils. Figure 4 shows the location of flightline 5. Cover conditions at these test sites included corn and soybeans. Surface soil texture ranged from loamy sand to sandy loam. This line was flown in both directions at an altitude of 500 feet.

3. GROUND TRUTH ACQUISITION AND PROCESSING

3.1 Soil Moisture

Ground sampling at the Maryland sites was performed by personnel from USDA and NASA. Data at the Delaware sites were collected by personnel from Delaware State College.

Gravimetric soil samples were collected using a 5 cm deep scoop with a total volume of approximately 85 cm³. The greatest number of samples were collected for the 0-5 cm soil layer. At the Maryland mites, a fewer number of samples were collected for both the 5-10 and 10-15 cm soil layer. For the Delaware sites the 5-10 cm soil layer was not sampled.

All gravimetric samples were placed in metal cans and sealed with electrical tape. These were weighed at the end of the day to obtain wet weights. Samples were then placed in a drying oven at 104°C for 24 hours and reweighed to obtain dry weights.



Figure 3. Delaware flightline 4 and fields.

ORIGINAL PAGE TY OF POOR QUALITY



7



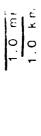


Figure 4. Delaware flightline 5 and fields.

Ð

1

The number of samples collected in the Maryland fields depended on the field size; however, no fewer than six samples/field were obtained. Data were obtained on a grid centered on the flightline with a surface sample every 150 m (500 feet). In most cases there were 12 points per field. Deeper depth samples were obtained near the field center at 2 or 3 locations.

Several different schemes were used at the Delaware sites. These fields were sampled depending upon access and layout. All fields except number 17 were sampled using a grid with a spacing of about 500 feet (150 m) between samples. Due to access problems, only a border and one path in Field 17 were sampled. The number of samples per field averaged 16 for the 0 to 5 cm soil layer and 4 for the 10-15 cm layer.

Gravimetric soil moisture values were averaged for each field on each date. This average was multiplied by the bulk density, described in the following section, to obtain the field average volumetric soil moisture values listed in Appendix I.

An effort was made to collect the samples within 2 hours of the aircraft flights. In some cases, data from the irrigated Delaware sites had to be deleted because of irrigations that were being performed.

On several sampling dates, especially at the Maryland sites, a significant portion of some fields was covered by standing water. Samplers were instructed that if a grid point happened to fall at a location with standing water, they were to note it as such in the field notebooks. The locations of the standing water followed very distinct patterns which in most cases coincided with local drainage. Comparing field average soil moistu a under these conditions to line samples of brightness temperature will require additional analyses beyond the detail presented in this report.



(4)

3.2 Bulk Density

Determination of soil bulk density for the 0-5 cm soil layer was based on a volumetric displacement procedure that utilizes a specially designed bulk density ring with a hook gage and three one-foot-long bolts. The bulk density ring is placed on the ground and secured by driving in the three bolts. A sheet of plastic film is used to line the inside of the cylinder. Using a water-filled 500 ml graduated cylinder, the bulk density cylinder is filled to the hook gage and the quantity of water is recorded. This is returned to the graduated cylinder. The soil from the inside of the bulk density ring is then dug out to the desired depth of measurement and placed in a sealed container. The plastic liner is replaced and the ring is filled again. This amount of water is recorded. The soil wet and then dry weights are measured. The volume of soil removed is equal to the difference between the two water volumes used to fill the bulk density ring. The bulk density is computed by dividing the dry weight by this volume.

Samples were collected several times over the study period at the Maryland sites, at least once in each field. Data were collected only once at each Delaware site after the completion of the experiment. Four points were sampled in each field.

All of the bulk density data collected over the experimental period were evaluated in terms of timeliness, tillage, cover, soils, and rainfall to estimate a bulk density value for every gravimetric sampling data.



Values assigned to each observation are included in Appendix I. In general, the following values were used:

Condition	Bulk dens Maryland	ity Delaware		
	- g/cm	-		
Recently plowed	1.11	1.26		
Tilled, not recently plowed	1.34	1.36		
No till, idle	1.48	1.34		

3.3 Soil Texture

Two sample cans were selected from one of the soil moisture sampling dates for each field. From each of these cans two samples were obtained (four total per field) to estimate the soil texture.

The procedure used is based on a kit (Code 1067) produced by LaMotte Chemical Products Co. It yields the fractions of sand, silt and clay. Based on numerous repetitions using this procedure, we have found that it produces consistent results.

Average texture results for each field based on the samples are listed in Table 1. Also listed in Table 1 are the USDA textural classifications based on sampling and the soils information derived from the soil surveys of the area (Soil Conservation Service, 1966 and 1971). With a few exceptions, the sampled textural classifications and the published soil textures were the same.

ORIGINAL PAGE 19' OF POCR QUALITY

Table 1. Field soil properties.

٧.												U	r	۲(JC	R	Q	U£	AL!	T	Y						
Sample bulk density	gm/cm ³	1,30	1.47	1.31	1.57	1.29	1.29	1.24	1.23	1.27	1.31	1.44	1.19	1.02	1.48	}	1.56	1.50	1.37	1	1.44	1.51	1.46	1.25	1.42	1.41	1.45
tensions Estimated	1/3 bar	27	27	21	24	26	25	22	27	23	24	27	27	25	26	;	26	13	21	1	25	20	17	17	12	12	12
	15 bar	12	12	4	80	7	9	9	12	7	11	∞	6	6	10	1	10	2	10	1	13	6	9	9	9	8	4
re at specific	1/3 bar	22	20	17	87	21	23	24	33	26	23	34	24	24	32	!	29	11	19	;	20	20	17	13	œ	6	12
Volumetric moisture Sampled	l bar	19	19	14	24	19	19	22	23	54	22	27	21	20	25	!	28	∞	16	1	18	17	15	11	7	œ	11
umetric Sam	3 bar	14	16	12	17	11.	13	16	15	21	18	17	14	15	17	ł	25	9	13	1	15	13	13	6	4	7	7
	15 bar	&	6	2	15	œ	∞	7	œ	14	12	11	∞	7	16	;	16	2	7	1	7	9	7	2	٣	٣	٣
	soil/texture	Mattapex loam	Othello silt loam	Othello silt loam	Matapecke silt loam	Sassafras loam	Mattapex silt loam	Mattapex silt loam	Othello silt loam	Mattapex silt loam	Mixed silt loam	Mattapax silt loam	Matapecke silt loam	silt	Matapecke silt loam	Johnston silt loam	Othello silt loam	Rumford loamy sand	Woodstown sandy loam	Woodstown loam	Woodstown loam	Sassafras sandy loam	Sassafras sandy loam	Sassafras sandy loam	Rumford loamy sand	Sassafras sandy loam	Sassafras sandy loam
Samp le	t »xture	Silt loam	Silt loam	Silt loam	Silt loam	Silt	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	Silt loam	1	Silt loam	Loamy sand	Sandy loam	-	Loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Loamy sand	Loamy sand
	clay %	13	10	2	2	က	0	~	13	2	12	7	∞	7	11	1	11	4	15	;	21	∞	က	7	9	-1	7
	Silt %	09	20	26	63	72	9/	62	24	9	20	89	71	62	27	;	27	20	31	;	34	41	37	ጟ	14	70	15
	Sand X	27	20	42	32	25	54	37	33	33	38	25	21	31	32	1	32	9/	75	1	45	51	09	62	8	79	83
	Field	-	7	٣	7	2	9	7	œ	6	10	11	12	13	14	15	16	17	18	19	70	21	22	23	54	25	56

3.4 Moisture-Tension Relationships

The volumetric moisture content of the soils at specific tensions was determined using a pressure plate tensiometer. In such a device, a soil sample in an open ended ring is placed in a container to which pressure, in this case bottled nitrogen gas, is applied at a specific level. The water in the soil which is held by a tension greater than the applied pressure stays while the lower tension water is extracted through a porous plate. These samples are weighed before and after drying to determine the gravimetric moisture content.

Samples were collected using a coring tool to obtain an undisturbed sample. Based on the volume of the ring, a bulk density value can be estimated. Moisture contents were determined for two samples per field at tensions of 1/3, 1, 3 and 15 bars. The 15 bar sample bulk densities must be estimated to obtain a volumetric moisture content because an unconsolidated sample must be used.

The average values for each field are listed in Table 1. Figure 5 shows the results for three of the soils at the test sites plotted in the manner in which they are normally presented in the literature.

An alternative method for estimating moisture-tension values has been developed by Rawls et al. (1983). In this procedure, texture information, estimated from soils maps or sampling, is used with a series of graphs to estimate the volumetric moisture at specific tensions. These graphs were developed using an extensive data base. In this case, the sampled texture data were used with the graphs to estimate the 15 and 1/3 bar moisture contents listed in Table 1. In general, the results are similar to those obtained using the pressure plate tensionmeters. The estimated values were higher, except for a few 1/3 bar samples. Considering the difficulties of

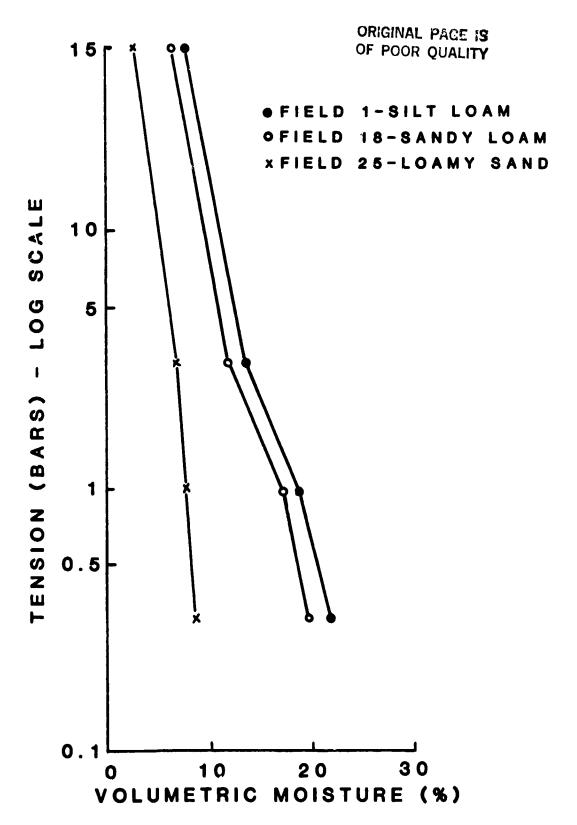


Figure 5. Laboratory moisture-tension relationships for selected Delmarva soils.

(4)

pressure plate analyses, the problem of statistical sampling and spatial variations, the graphical procedure appears to yield consistent and reliable results.

3.5 Soil and Surface Temperatures

Soil temperature data were collected using metal-dial type temperature probes at depths of 5 and 15 cm. The 5 cm values were obtained at almost all soil moisture sampling points. Fifteen cm measurements were obtained at all 15 cm soil moisture sampling locations, 3 or 4 near the field center line. Observed within field variations were typically less than 1°C at both depths.

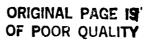
Surface soil/canopy temperatures were obtained using a hand-held thermal infrared radiometer. The sampling procedure involved the person walking from the edge to the center of the field and back and estimating the average response. All temperature data are listed in Appendix I.

3.6 Cover Conditions

The predominant crops on Delmarva peninsula are corn and soybeans. Corn is planted in early to mid May and soybeans in late May. Due to wet field conditions the soybean plantings were delayed this year.

On March 14, 1983, all of the Maryland sites had stubble or weed cover. Figure 6a illustrates the density of corn stubble. Soybean stubble results in a higher percentage of cover, as shown in Figure 6b.

In early May, most of the fields were planted in corn with the plants just beginning to emerge. By the beginning of June, the corn was between 10 and 30 cm in height with less than 10% ground cover as shown in Figure 7. Heavy rains during this period made the soil surfaces fairly smooth in the tilled fields. At the end of June, some of the fields had close to 100% ground cover and some were just being planted with soybeans.







В

Figure 6. Ground cover conditions on March 14, 1983 at the Maryland sites - V) corn stubble and B) soybean stubble.



Figure 7. Fills communica (field b) in tune 2, 1983.



Figure 8. Corn field with sovbean stubble (field 9) on June 2, 1985.

(+)

Several of the corn fields were not tilled, as a result, these usually had a ground weed cover and/or a heavy mulch or stubble cover. No till farming usually results in less soil surface evaporation due to the presence of the stubble. Figure 8 illustrates the ground cover in a corn field with a dense soybean stubble cover. Other fields had a weed cover for most of the study. Figure 9 illustrates the typical cover conditions.

The Delaware flightlines included a wider variety of cover conditions. Fields 17 and 18 were vegetable crops and field 19 was mature barley.

Observations during the study period were assembled and coded. For each field the following variables were estimated for each flight:

- 1. Crop
- 2. Percent ground cover
- 3. Height
- 4. Tillage
- 5. Surface roughness
- 6. Row direction

Crop type codings that are used in Appendix I are listed in Table 2.

Percent cover was assigned a value between 0 and 100%. Crop height was

measured in centimeters. The tillage treatment codes are listed in Table 3

and the visually estimated surface roughness codes are listed in Table 4.

Row direction varied and for certain fields the reference row direction depends upon the flightline that was being considered. Codings used for the row directions are listed in Table 5.

ORIGINAL PAGE IS OF POOR QUALITY



Figure 9. Condition of a weed covered field (field 10) on June 2, 1983.

Table 2. Crop	type codes	
---------------	------------	--

Table	2. Crop type codes.	Table ". Tillage condition codes.							
Code	orcp type	Code	Tillage condition						
1	Bare soil	;	Tilled						
2	Corn	•	No till corn stubble						
3	Soybeans	3	No till soybean stubble						
4	Corn stubble								
5	Soybean stubble								
6	Mixed								
7	Barley								
_									

Table 4. Surface roughness codes.

Deciduous trees

Table 5. Row direction codes.

Code	Roughness	Code	Direction relative to flightline
1	No recent tillage	1	Parallel
2	Smooth	2	Perpendicular
3	Moderate	3	Diagonal
4	Rough	4	None

During the course of the study, a limited number of corn biomass samples were collected. On the average, 10 plants were removed, weighed, dried and weighed again to obtain the wet and dry biomass values per lant. Vegetation water content was computed by subtracting the dry weight from the wet weight. The per plant values were then multiplied by the plant density of approximately 6.6 plants per square meter to obtain the values on a square meter basis. Sample data are listed in Table 6. These values for an immature corn crop can be compared to data presented by O'Neill et al. (1983) for a mature canopy which ranged from 5000 to 7000 gm/m² for wet biomass. Based on vegetation effects models such as that presented by Jackson et al. (1982), the biomass observed on these fields should not have a significant effect on the sensitivity of the microwave brightness temperature to soil moisture variations.

(+)'

Table 6. Corn biomass sample data.

				Per plant		Per	r square meter				
Field	Date	Plant height (cm)	Wet Biomass	Dry Biomass	Water content -gr	Wet Biomass	Dry Biomass	Water Content			
		<u> </u>				<u></u>					
1	6/15/83	90	132	9	123	871	59	812			
1	6/27/83	120	336	27	309	2218	178	2040			
6	6/15/83	30	46	4	42	304	26	278			
13	6/15/83	45	76	5	71	502	33	469			
13	6/22/83	60	281	28	253	1855	185	1670			
16	6/15/83	15	13	1	12	86	7	79			

Two of the fields that are reported in Appendix I were areas covered by deciduous trees. Field 15 was a cross section of the Choptank River which was obscured by trees. Due to the heavy rains during the course of the study, the area covered by water varied. No ground verification of soil or water-covered area was obtained, only video data were used. Field 27 was a forested area that all three Maryland flightlines crossed. At times standing water was observed within this area.

Field 17 was planted in peas in the early period of the study. The 15 cm rows made access difficult. A center pivot irrigation system was present in this field. Field 18 was planted in several vegetable crops, including squash and cucumbers, and was partially bare. This field also had a center pivot system. The only other field with a sprinkler irrigation system was field 23. which was planted in sweet corn.



Field 19 had a mature barley cover over the entire period of study. It can be assumed that the water content of the crop was very low based on other studies involving winter wheat (O'Neill et al. 1983). Field 20 was discarded because the cover conditions were mixed corn and pasture.

4. CLIMATOLOGICAL DATA

Rainfall data were available at several weather station locations near the flightlines as shown in Figura 1. The Centerville, Denton, Royal Oak, Dover, and Milford data were extracted from the "Climatological Data for Maryland and Delaware" published monthly by NOAA. Delaware State College provided the rainfall data at the Darling and Willow Grove sites.

The most complete and detailed record was from the class A station maintained by the Wye Agricultural Experiment Station (Wye Institute). This station included a weighing bucket raingage, evaporation pan, temperature, dew point, solar radiation, and wind speed. Data, excluding the raingage, are recorded in analog form and can be evaluated at 1-min intervals. The Wye Agricultural Experiment Station provided a 1-hour interval listing from which the daily values listed in Appendix II were computed for the period of May and June, 1983. Data for the Wye Institute raingage were obtained from strip charts.

To illustrate the general meteorological conditions, Figure 10 was developed using the daily evaporation pan readings. This is a cumulative plot of evaporation minus rainfall, therefore positive values indicate more evaporation than rainfall. May started off with some very large rainfalls. The first few weeks of June were dry and at the end of June there were a few large storms. As described above, the daily evaporation pan readings reflect

ORIGINAL PAGE IS OF POOR QUALITY

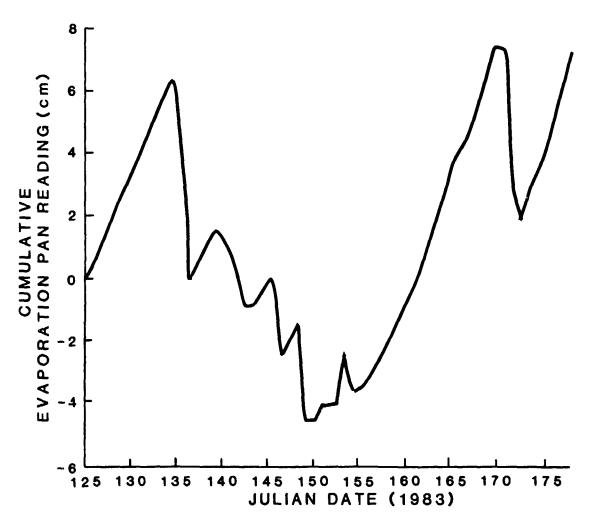


Figure 10. Cumulative evaporation pan readings at the Wye Institute for May and June, 1983.

(+)

both evaporation and rainfall. Hourly readings were reviewed to determine the separate rainfall and evaporation components. The estimated pan evaporation valves are listed in Appendix II.

A detailed listing was not provided for the March 14, 1983, flight. Climatological records for the two weeks preceding the flight indicate that there was about 4 cm of rainfall with an event of approximately 1 cm on March 12, 1983. Daily air temperatures ranged from 35°F to 55°F on the day of the flight and the few days before. No freezing conditions were present within the preceding two weeks.

Pan evaporation is directly related to the potential evaporation. A pan coefficient is used to relate the pan value to a lake evaporation estimate. This coefficient must be less than one and is usually about 0.7 (Jensen, 1973). Also, it can be related to the potential evapotranspiration of particular crops. As described in Jensen (1973) the coefficient for an area like the Wye Agricultural experiment station, considering the immediate surroundings of the weather station, should range from 0.6 to 0.75.

Potential evapotranspiration from grass can also be computed from the available meteorological data and the combination equation developed by Penman (Jensen, 1973). Using the average air and dew point temperatures, the wind speed and solar radiation listed in Appendix II, a daily potential evapotranspiration value was computed for each day. Results are listed in Appendix II.

Pan evaporation and computed potential evapotranspiration were compared for the period of study. An optimization program was used to determine the value of a coefficient that would minimize the sum of squares of the residuals between the two. This analysis indicated that a pan coefficient of 0.65 was

1.1

best and had a coefficient of determination of approximately 0.92. These analyses indicate that the pan is performing as expected as an indicator of evaporation.

5. AIRCRAFT AND SENSOR SYSTEMS

The sensor system consists of an L band 3 beam push broom microwave radiometer, a thermal infrared scanner, a multispectral scanner, a photographic camera, a video camera and recorder, and a LORAN-C navigational system.

5.1 Microwave Radiometer

Additional details on the push broom microwave radiometer (PBMR) are presented in Table 7. It is a 3 beam L band system centered at 0° and $\pm 30^{\circ}$. The 3db (half power) points of the beams are located at roughly $\pm 10^{\circ}$ of the beam center position. For the main beam this results in a swath (ground resolution) of 0.35 times the altitude. The two side beams will have swaths about 0.53 times the altitude. Beam centers for the side beams will be ± 0.58 times the altitude. Total coverage for the three beams will be a swath equal to 1.68 x altitude. At 150 m (500 feet) this will be 250 m (840 feet), at 300 m (1,000 feet) it is 500 m (1,680 feet), and 675 m (2,520 feet) at 450 m (1,500 feet). Figure 11 illustrates the geometry of the PBMR system.

Table 7. L Band radiometer specifications.

1,413.5 MHz

Antenna:

Center frequency
Bandwidth
Polarization
Beamwidth
Beam efficiency
Beam directions

Horizontal 20° at 3db points 90 percent null to null 0°, +30°, left and right of center

30 MHz to 100 MHz, variable

Radiometer:

Type
Center frequency
Bandwidth
Temperature sensitivity
 (short term stability)
Accuracy (calibration stability)
Operating temperature range
Integration time (sec)
Operation environ

Dicke
1,413.5 MHz
12.5 MHz
T 0.7 °K, 1 sec integration time

2°K
+40°C to -40°C
0.5, sec
unpressurized aircraft to 3,000 m





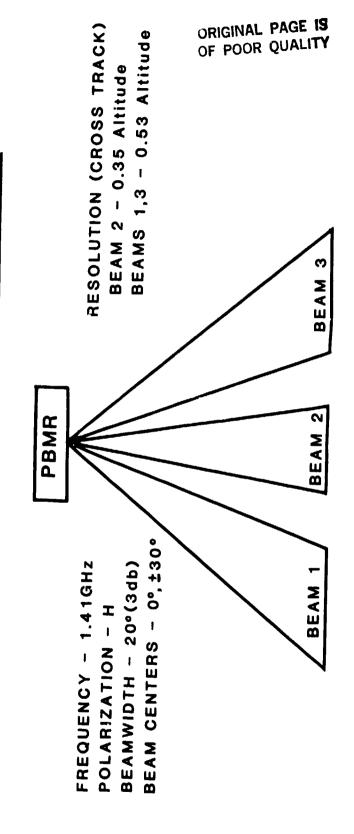


Figure 11. Ground coverage and specifications for the push broom microwave radiometer.



(4)

5.2 Heat Capacity Mapping Radiometer (HCMR)

The Heat Capacity Mapping Radiometer is a two channel scanning/imaging radiometer. Channel 1 includes the spectral band from 0.55 - 1.1 microns and can be used to estimate albedo. The second channel provides a thermal infrared measurement over the interval of 10.5 - 12.5 microns. Figures 12 and 13 show the relative response of the two channels as a function of wavelength.

The instantaneous field of view (IFOV) of the sensors can be up to 0.83 milliradian (0.046°) ranging from ± 45° off nadir. At an altitude of 300 m (1000 feet) the nadir beam this would generate a ground resolution of 0.3 m (1 foot) resolution cell. A detailed description of the sensor system can be found in Bohse et al. (1979).

The HCMR was operated at a scan rate that results in a gap of approximately 6 m between scans at an altitude of 300 m (1000 feet). At this rate, there would be approximately 50 scans per field which was considered adequate for this investigation.

5.3 Ocean Color Scanner (OCS)

The Ocean Color Scanner that was used in these studies is called UCS II and is a modification of an earlier system. OCS II has 12 channels as opposed to the 10 of the earlier version.

Center wavelengths of the 12 channels are shown in Table 8. Unfortunately, spectral response curves for this system are not readily available. However, the curves for the 10 channel system are presented in Figure 14 to illus rate typical conditions.

The IFOV of the OCS can be 3.5 milliradians (0.2°) and it scans $\pm 45^{\circ}$ from nadir. At an altitude of 300 m (1000 feet) the footprint would be 1 m (3.5 feet). Additional details on this sensor system can be found in Blaine et al. (1977).



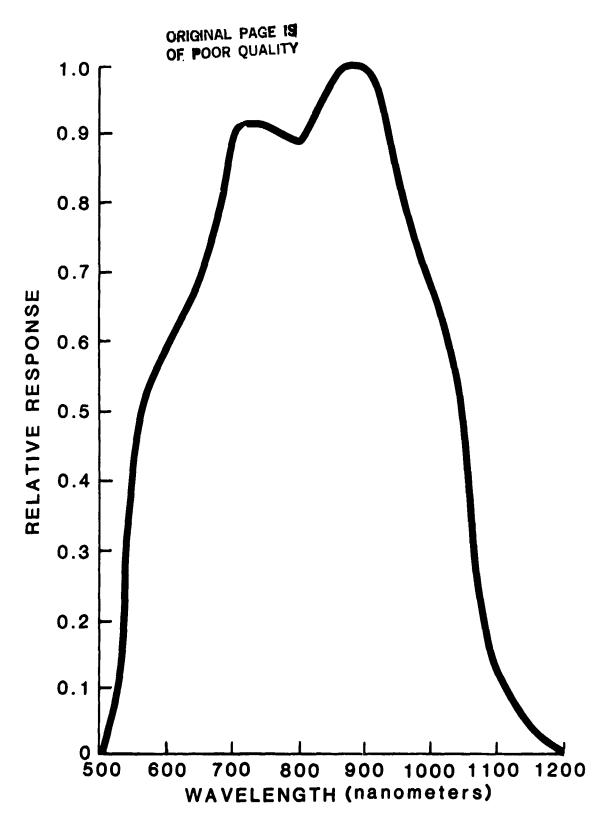


Figure 12 HCMR detector response for channel 1.



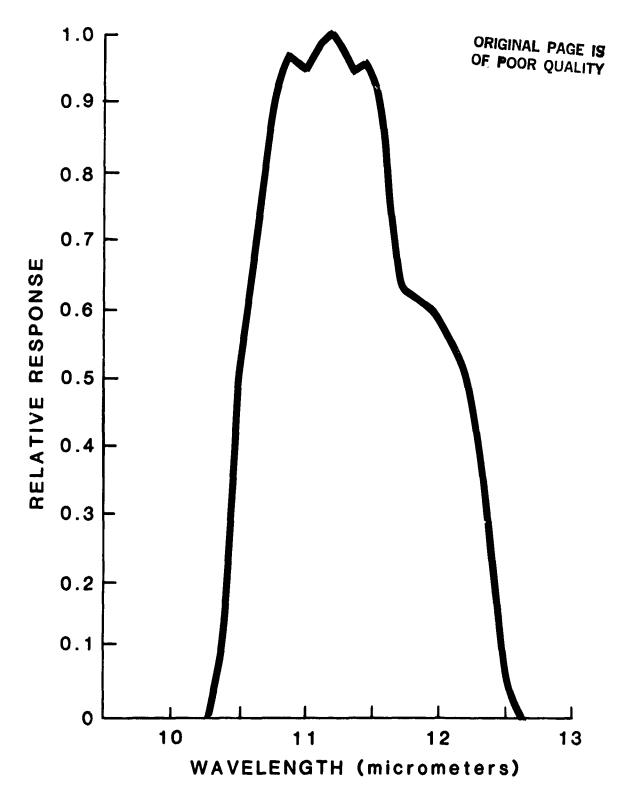


Figure 13. HCMR spectral response for infrared channel.



ORIGINAL PAGE IS OF POOR QUALITY

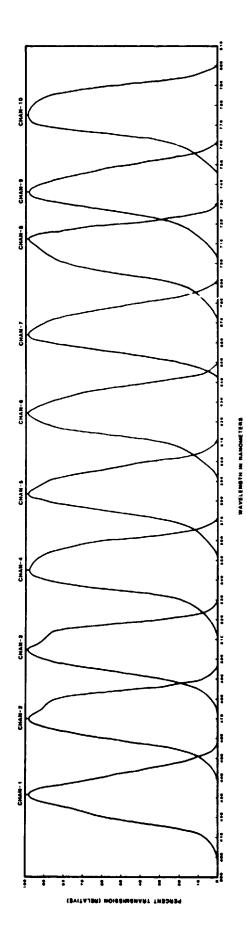


Figure 14. Spectral response of the 10 ocean color scanner channels.



Processing 12 channels of high resolution data is impractical if rapid turnaround is desired. It is also unnecessary for this investigation.

Therefore, only two channels will be processed for the biomass estimation procedures; channels 7 and 11. Ground coverage of this sensor is similar to that of the HCMR.

Table 8. - Center wavelengths of the OCS II.

	Center
Channel	wavelength
	(nm)
1	425
2	464
3	509
4	549
5	587
6	631
7	669
8	711
9	756
10	793
11	828
12	863

The photographic camera used was a 35 mm system with color film. Clock time was recorded on the image. 35mm color positive transparencies were generated for each flight. The primary image format used for ground-air time referencing were the color video tapes. These also had clock time on the image and were inexpensive. The aircraft on which the systems were mounted is a Short SC7 Skyvan, which is a twin engine plane.

5.4 Data Processing and Calibration

When the calibrated radiometer data were available for one-half second intervals, coverage for each field and run were extracted to compute an average and standard deviation for the brightness temperature. Start and stop times of

1-)

field boundaries were determined by reviewing the video tapes or photographs.

At least one-half second of data was deleted from the beginning and end of the coverage to avoid minor variations related to aircraft parameters.

In addition, coverage of each field was reviewed to determine if any mixed conditions resulted from flight line drift or changes in aircraft parameters. If these conditions were present, the data for that beam and field were not used.

6.0 RESULTS

Preliminary analyses of the data set focused on the relationship between the center beam (C) brightness temperature (T_B) and the volumetric soil moisture (VSM) in the 0 to 5 cm soil layer. Each field was treated as an individual data set.

Figure 15 illustrates the type of relationship that was observed for a tilled corn field (Field 1) with rows perpendicular to the flightline. The consistency of the response between different runs on the same day is very good. Measurements cover a wide range of soil moisture and brightness temperatures which adds reliability to empirical relationships. Some of the variation observed in Figure 15 can be explained by the increase in canopy. Data from day 173 had nearly 100% corn cover and the brightness temperatures are higher than those we would expect from bare soils.

Field 1 was one of the longer rame frames available and had a uniform set of cover and soil moisture conditions on each date. Therefore, this field will be used as a basis of comparison to other fields.

Several other fields at the Maryland site were similar in soils and cover to field 1; these were 4, 8, 13, and 14. Graphical analysis of data from these fields showed that the patterns were very similar, although, the variability



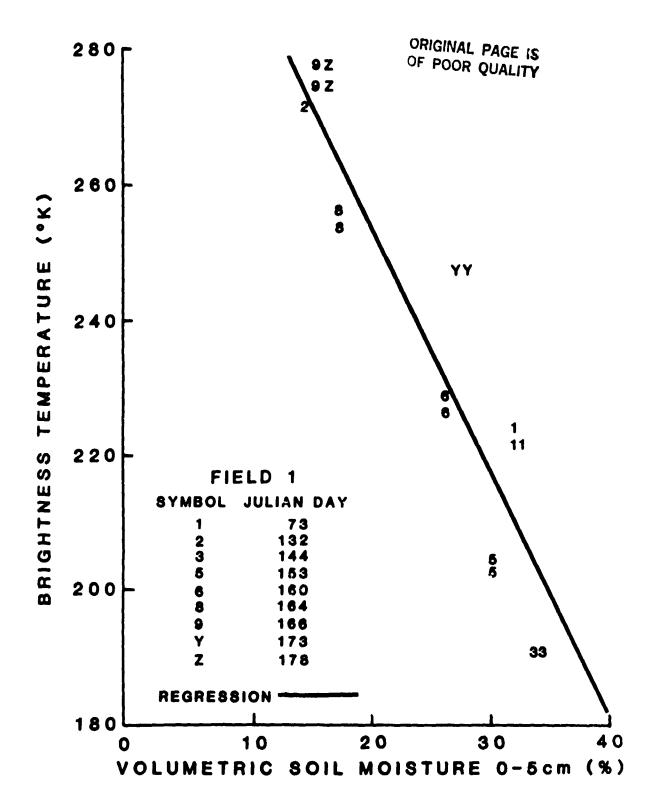


Figure 15. Brightness temperature vs soil moisture, field 1, center beam.

(+)

was greater, as shown in Figure 16 for field 13. Regression parameters for brightness temperature and soil moisture listed in Table 9 indicate that these 5 fields have similar intercepts and slopes. The coefficient of determination R² is quite a bit smaller in fields 8, 13, and 14, which reflects the variability observed in the graphs. A major portion of the variability in these other fields can probably be attributed to differences between the average soil moisture of the field and the area actually covered by the sensor.

Two of the fields, 2 and 7, remained in a bare soil condition through most of the experiment. However, they were tilled and planted for the last two flights. Regression results shown in Table 9 indicate similar parameters for the two fields. Results were also similar to those obtained for field 1.

Three fields at the Maryland site, 3, 10, and 12, were not planted through most of the study but were covered with stubble and weeds. Qualitatively, field 10 had the densest cover, field 12 the smallest amount, and field 3 was in between. Plots of T_B versus VSM revealed that the dynamic range of observed soil moisture was related to the vegetation cover density, as illustrated by comparing Figure 17 for field 3 with Figure 16 for field 1. As expected from previous research, the observations of B_T on these fields tended to be greater than those observed over the corn field with less cover.

The effect of the denser canopy of field 10 is apparent in Figure 18.

These results are particularly interesting because on day 173 the field was plowed and we see that the observation is very close to the field 1 regression. Once the canopy was removed, the field dries out faster and the data from the last flight show this to be crue.



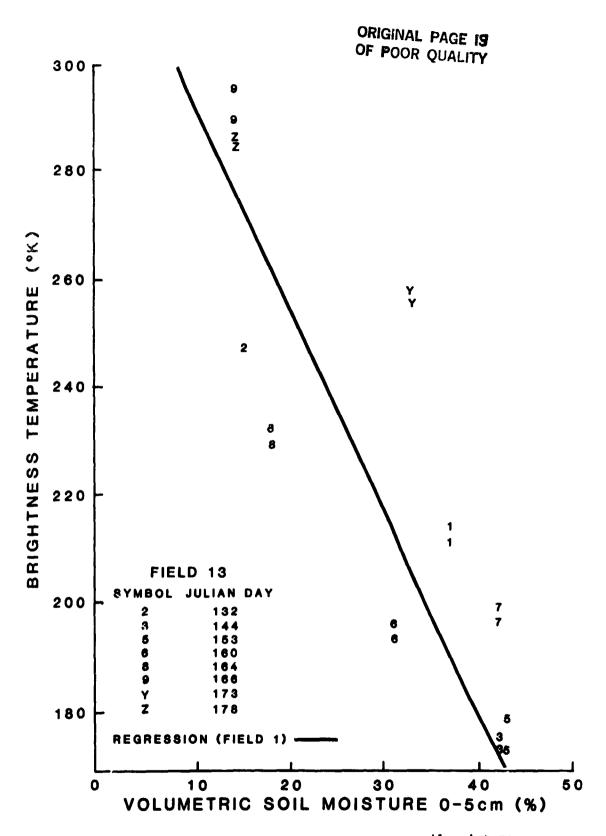


Figure 16. Brightness temperature vs soil moisture, field 13, center beam.



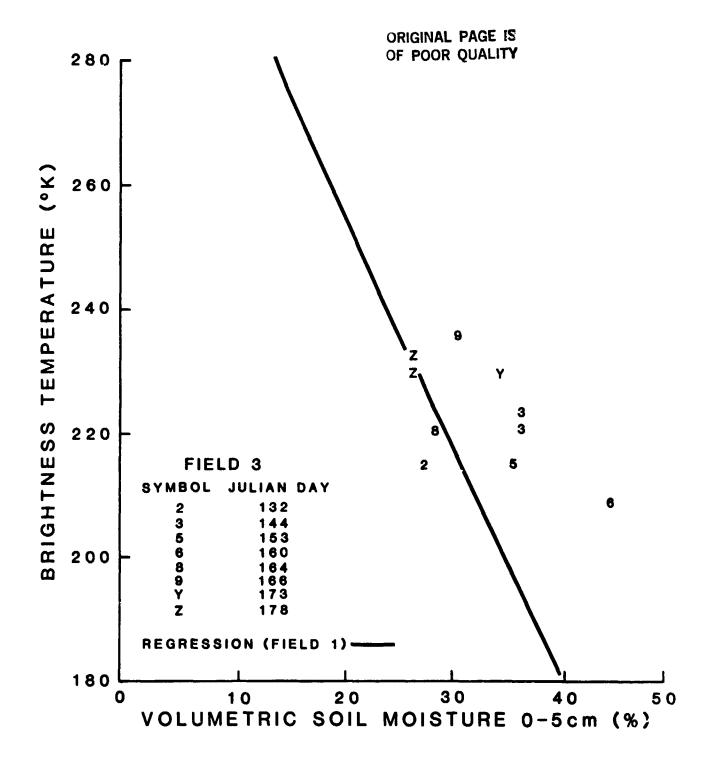


Figure 17. Brightness temperature vs soil moisture, field 3, center beam.

ORIGINAL PAGE IS OF POOR QUALITY

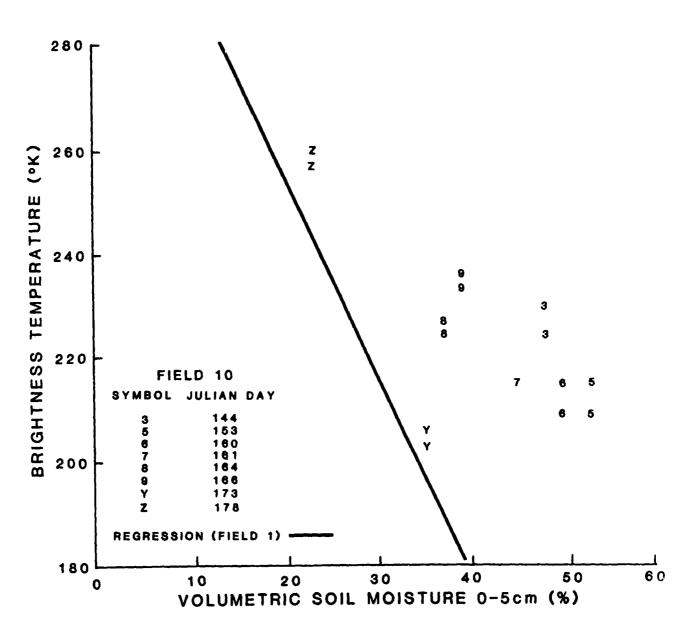


Figure 18. Brightness temperature vs soil moisture, field 10, center beam.

1

ORIGINAL PAGE IS OF POOR QUALITY

Table 9. Brightness temperature and 0-5 cm soil moisture linear regression results.

			Li	near regression	n parame	ters			
	TBC* =	a+b(VSM	1)	TBL** =	a+b(VSM1)	TBR*** =	a+b(VSM1	.)
Field	Intercept (a)	Slope (b)	R ²	Intercept (a)	Slope (b)	R ²	Intercept (a)	Slope (b)	\mathbb{R}^2
1	328	-3.6	. 84	334	-4.2	.88	344	-4.7	.92
2	305	-2.6	.85	293	-2.5	.89	298	-2.7	.81
3	259	-1.1	. 44	218	. 2	.00	219	. 2	.02
4	221	-3.4	.76	318	-3.7	.80	262	-1.8	.35
5	317	-2.6	. 32	317	-3.0	.31	321	-3.0	. 32
6	345	-4.3	.69	320	-4.3	.68	318	-4.2	.61
7	319	-2.9	. 64	303	-2.8	.61	296	-1.9	•55
8	323	-3.2	.67	315	-3.4	.68	326	-3.2	.73
9	244	-0.8	. 25	255	-1.4	. 44	260	-1.0	.18
10	269	-1.1	.43	248	-0.7	.18	263	-1.1	. 37
11	322	-1.4	.73	321	-3.6	.78	316	-3.4	.69
12	285	-2.2	. 64	283	-2.5	.66	262	-1.7	.46
13	318	-3.1	.71	325	-3.4	.78	299	-2.6	.75
14	320	-3.3	.72	322	-3.7	.85	299	-2.6	.72
15									
16	227	-0.6	.11	228	-0.9	.18	204	-0.0	.00
17	343	-6.4	. 75	338	-6.8	.73	343	-6.4	.77
18	334	-4.8	.85	322	-5.1	.85	335	-5.2	.83
19	261	-1.4	.75	233	-1.0	. 44	265	-1.8	.18
20									
21	293	-2.0	.68	284	-1.8	•57	286	-1.5	.38
22	301	-2.8	. 32	296	-3.2	.51	293	-3.2	.42
23	334	-5.9	.67	322	-5.8	.65	305	-4.6	.83
24	311	-4.8	.68	309	-6.3	.91	305	-5.5	.79
25	317	-3.6	.85	299	-1.9	.62	318	-4.6	.82
26	308	-2.6	.87	300	-2.9	.78	300	-2.4	.78
27									

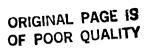
^{*} TBC = Center beam brightness comparative

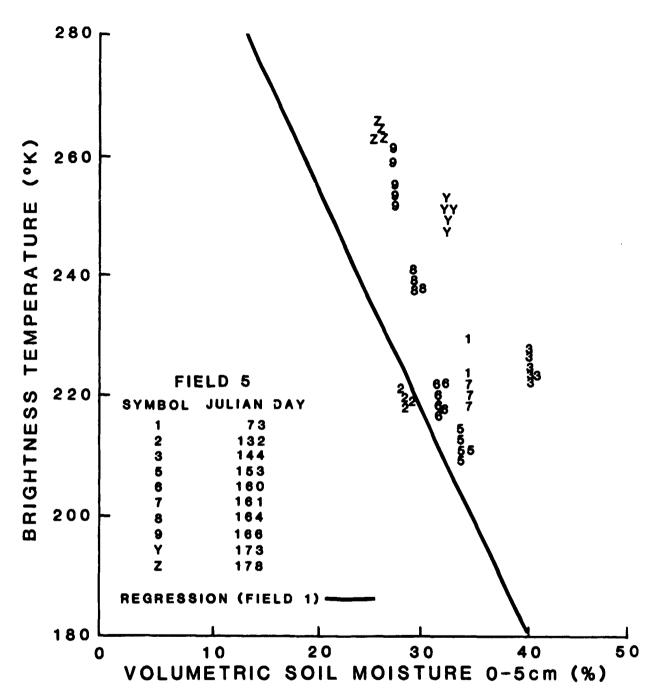
Regression results from these fields are listed in Table 9, however, the limited range of observed soil moisture values makes them relatively useless on their own.

One set of conditions that was observed in this study that had not been previously analyzed was mulched no till fields. Four fields, 5, 9, 16, and 22,

^{**} TBL = Left " "

^{***} TBR = Right " "





e Res L 100

Figure 19. Brightness temperature vs soil moisture, field 5, center beam.

t)

were no till corn with relatively dense ground covers of soybean mulch/stubble. As a result of the mulch cover, there was less surface evaporation than on a tilled field; this resulted in a small range of observed soil moisture values. Figure 19 illustrates the typical relationship for field 5. A general interpretation of these results is that since the T_B exhibits a large dynamic range and the soil moisture does not, the soil moisture we are using is not indicative. Since there is a mulch layer present the moisture is fairly uniform with depth at the surface. This might suggest that the changes in T_B are the result of something related to the mulch. Perhaps there is a build-up of moisture just under the mulch that affects the response. This aspect needs further study.

Data collected over fields with lighter vegetation cover at the Delaware sites, such as field 23 shown in Figure 20, indicate a greater sensitivity of $T_{\rm B}$ to VSM. This result is typical of the change we expect between silt loams such as those at the Maryland sites, and the sandy loams at the Delaware sites.

Field 19 had a mature barley cover through the series of flights. For all practical purposes, we can assume it to be the same cover on each day. Under these conditions, the effect of soil moisture changes under the canopy on the observed T_B can be evaluated. Figure 21 shows the plot of the data. There appears to be a distinct trend, although, the absolute level is not consistent with results from Field 1.

Analysis of the data collected by the two side beams was performed through plots and regressions. Figure 22 shows the left and right beam measurements and the center beam regression for field 1. In this case there is no obvious difference between the two beams. Also, the regression from the center beam

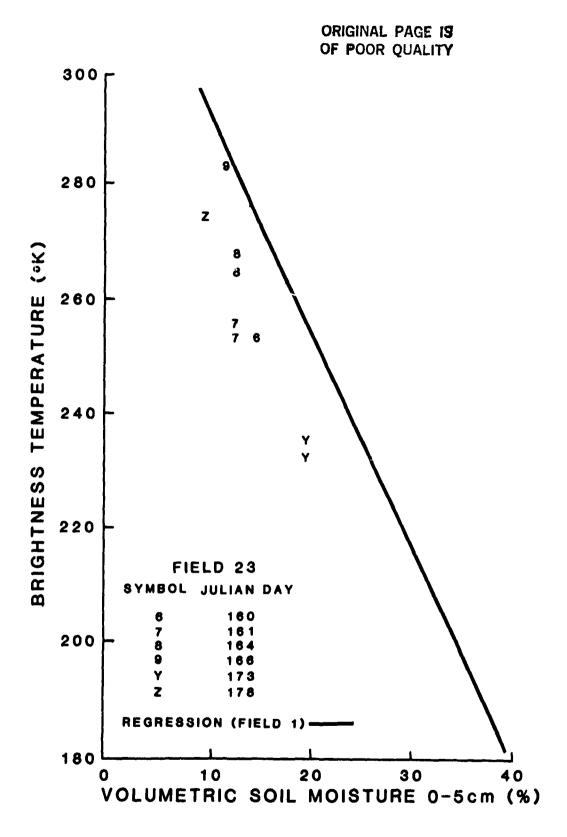


Figure 20. Brightness temperature vs soil moisture, field 23, center beam.

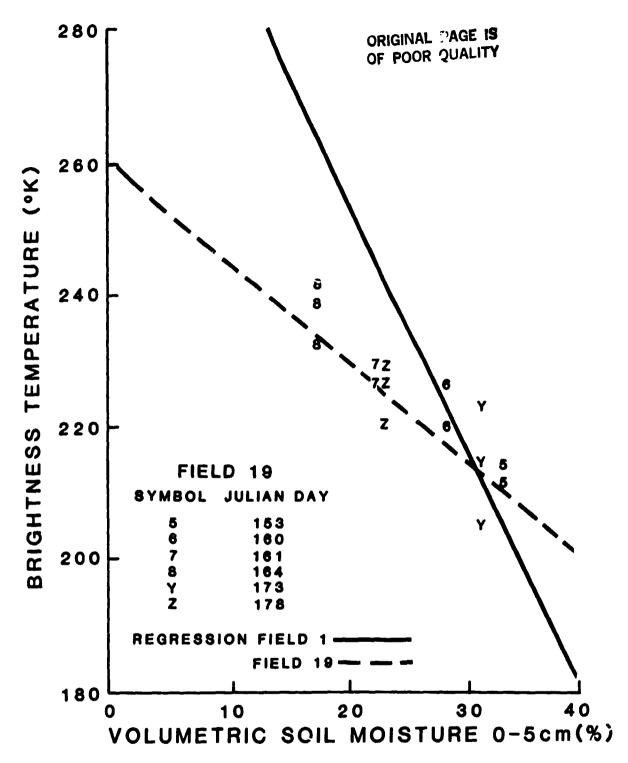


Figure 21. Brightness temperature vs soil moisture, field 19, center beam.

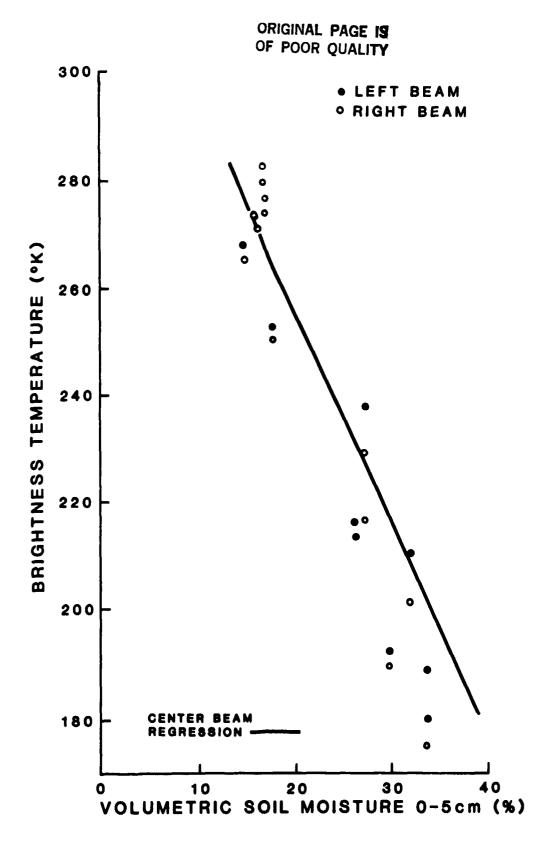


Figure 22. Brightness temperature vs soil moisture, field 1, side beams.

data explains the side beam observations fairly well under dry conditions. Previous research, such as the study by Wang et al. (1983), have shown that there is little difference in the T_B between 0 and 30° incidence angles for bare soils under dry conditions, however, as the soil becomes wetter the difference increases. These results exhibit these same trends.

Observations on the barley field (19) shown in Figure 23 suggest a uniform decrease in response for the side beams as compared to the center beam. These results must be interpreted with caution since there were no dry conditions observed. Comparisons to winter wheat data reported in O'Neill et al. (1983) show that the expected decrease in T_B between 0° and 30° incidence angles should be on the order of 15°K for this range of soil moisture conditions, which is approximately the amount observed here. Regression analyses of the side and center beams, which are summarized in Table 9, show that there is a strong linear relationship on a field basis with the exception of the no till and weed/stubble covered field 5. In addition, in most of these same fields there were poor linear relationships for the left and right beams. These results once again suggest spatial soil moisture patterns in these fields.

Due to the frequency of the flights in May and June and the variation in weather conditions, the data collected in this study are suitable for the analysis of temporal patterns of T_B and their relationship to climatic variables beyond surface soil moisture. For the present time, the analysis will use the cumulative evaporation pan values collected at the Wye Agricultural Experiment Station. This value represents an approximation of the cumulative outflow and inflow to the soil column. Pan evaporation is usually greater than free water or lake surface evaporation which is used to

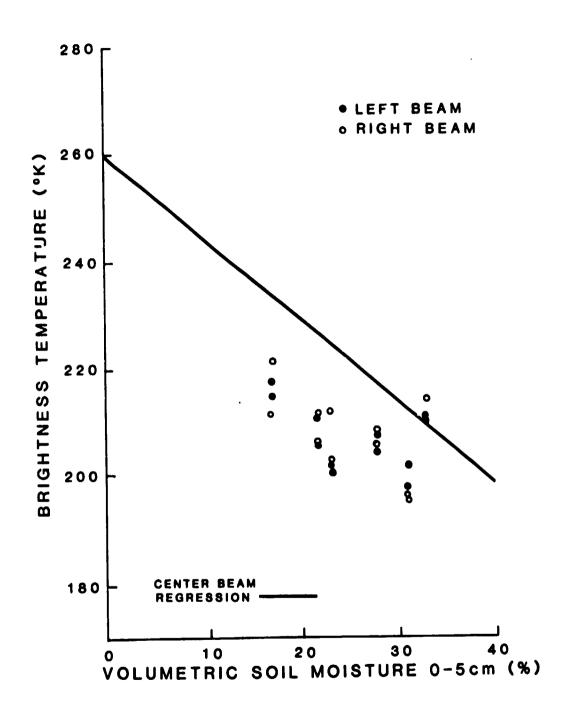


Figure 23. Brightness temperature vs soil moisture, field 19, side beams.

(+)

approximate the potential evapotranspiration. Potential evapotranspiration is used in conjunction with soil and vegetation parameters to compute actual evapotranspiration.

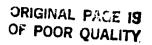
The cumulative daily evaporation pan data (ΣE_p) will be positive when evaporation for the period exceeds rainfall and vice versa. It was set to zero on Julian day 124 and plotted in Figure 10.

Figure 24 includes a plot of T_B as a function of Julian day. On its own it is difficult to interpret, however, when it is plotted with the $^{\Sigma}E_p$ relationship using an arbitrary scale, a remarkable similarity of pattern is apparent. The T_B is responding in a nearly identical way as the $^{\Sigma}E_p$. During the extended drying period in early June the relationship is very strong. This might be expected with a bare soil condition. However, similar patterns are observed between the last two flights when there was nearly 100% cover.

With these results in mind, data from several other fields were analyzed. Figure 25 shows the results obtained for field 3 (tall weeds). Here the dynamic range is much less, however, the pattern is still apparent although not as dramatic.

Figure 26 is a plot of the data collected over field 5. This response is between the two extremes of fields 1 and 3, which is expected based on its cover. What is very important here is the fact that the T_B values follow a very clear pattern which, based on Figure 17, doesn't necessarily correspond to the VSM in the 0 to 5 cm soil layer.

Data collected over the two forest covered fields, 15 and 27, did not include ground conditions. Therefore, the only comparison that can be made is to general climatic variables. Having shown that there is reason to believe that a relationship exists between the T_B and ΣE_p , comparisons on the forest sites is possible.



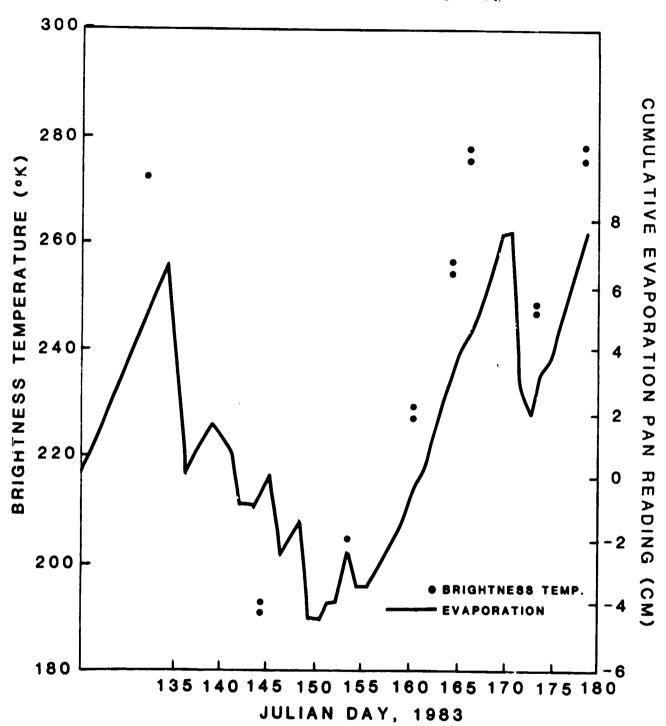


Figure 24. Brightness temperature vs Julian day and cumulative evaporation pan values, field 1, center beam.



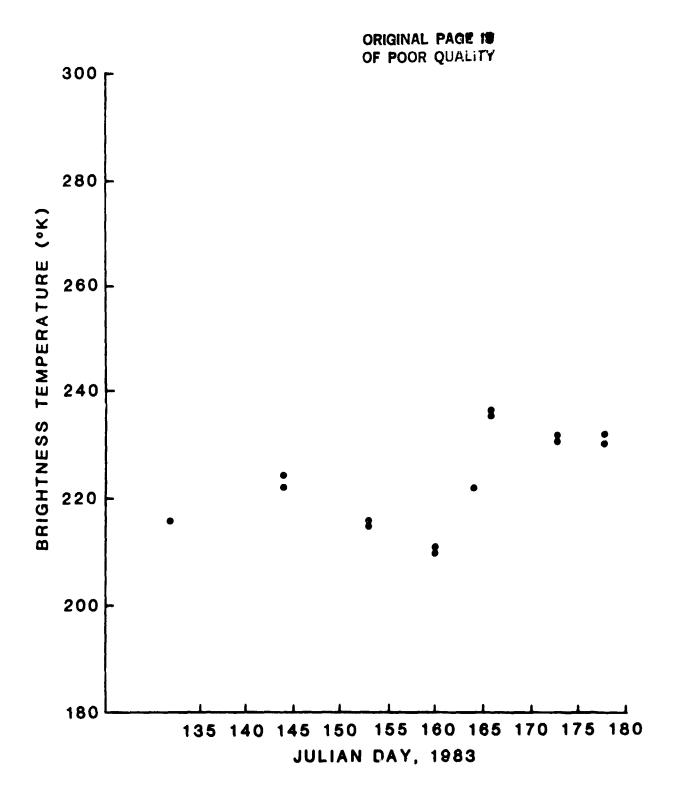


Figure 25. Brightness temperature vs Julian day, Field 3, center beam.

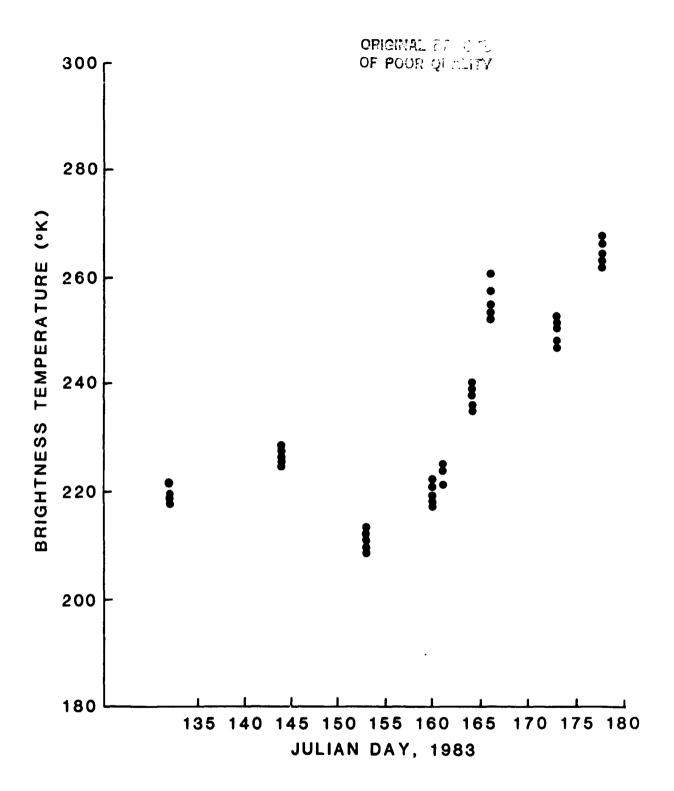


Figure 26. Brightness temperature vs Julian day, field 5, center beam.

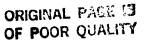
Figure 27 is a plot of the data collected over field 27. A general trend similar to those observed in the weed field is present, however, the day-to-day variation is small and on the same order as the variation on a given day.

The results over field 15, the Choptank River cross-section, are quite different. As shown in Figure 28, the pattern is quite distinct. It is hypothesized that the reason for the variation in $T_{\mbox{\footnotesize B}}$ is the extent of the flooded area beneath the trees. As the streamflow receded the width of a shallow channel such as this section of the Choptank River also recedes.

Another aspect of the forest sites that was considered was what difference might be expected in T_B between beams with such a dense cover. Responses for field 27 showed no consistent difference on any day. Greater variability was observed for field 15, which is probably related to spatial patterns.

7. SUMMARY

In May and June, 1983, NASA and USDA cooperated in the verification of a multi-sensor aircraft system developed to study soil moisture applications. This system consisted of a three beam push broom L band microwave radiometer, a thermal infrared scanned, a multispectral scanner, video and photographic cameras and an onboard navigational instrument. Ten flights were made of agricultural sites in Maryland and Delaware with little or no vegetation cover. Comparisons of aircraft and ground measuremnts showed that the system was reliable and consistent. Time series analysis of microwave and evaporation data showed a strong similarity that indicates a potential direction for future research.



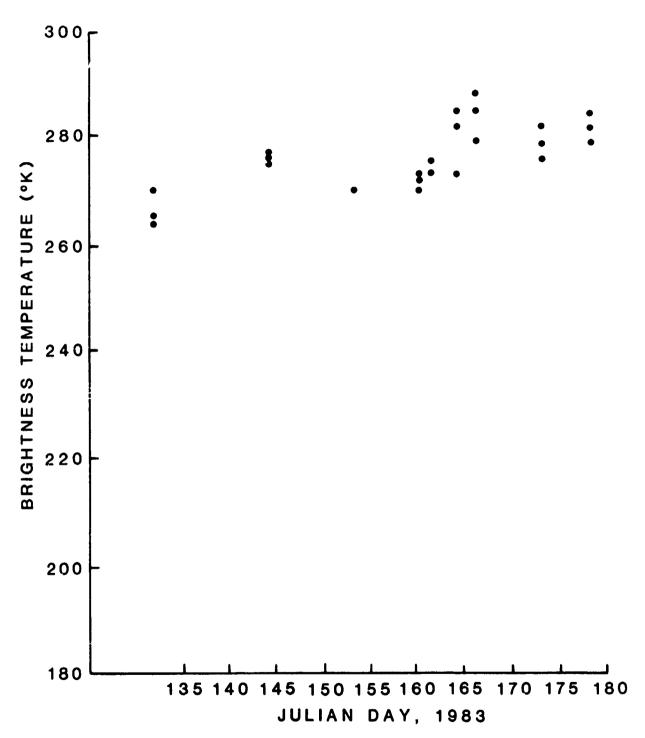


Figure 27. Brightness temperature vs Julian day, field 27, center beam.

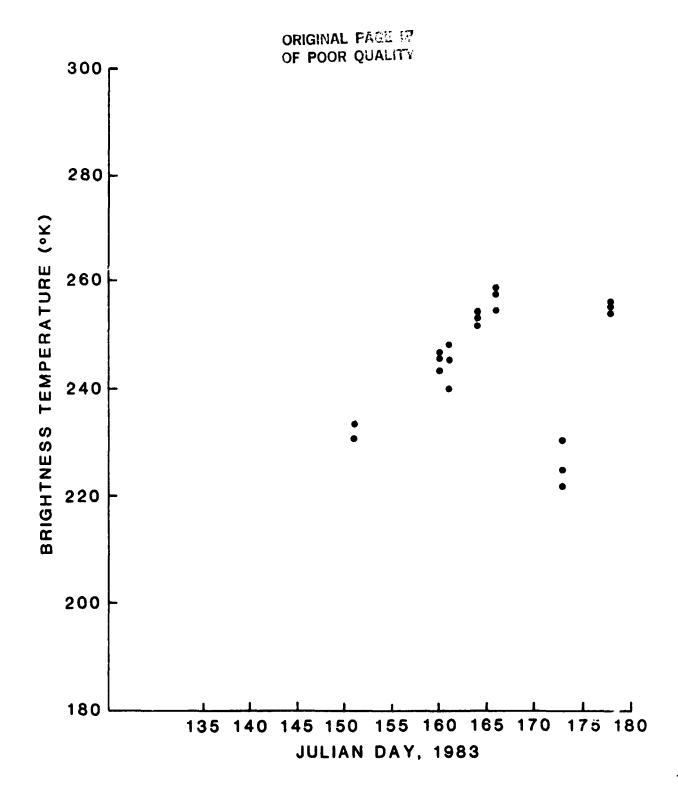


Figure 28. Brightness temperature vs Julian day, field 15, center beam.

(4)

8. ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to the personnel of the Hydrology Laboratory, USDA/ARS/BARC, the Hydrological Sciences Branch NASA/GSFC and the Department of Agricultural and Natural Resources of Delaware State College for their assistance in the data collection effort. We are especially thankful to Dr. Russ Brinsfield of the Wye Agricultural Experiment Station for his assistance and cooperation in this project and to the individual farmers who allowed us to sample their fields.

9. REFERENCES

- Blaine, L. R., C. J. Murphy, III, and W. L. Barnes, 1977. The Ocean Color Scanner Experiment, GSFC X-Docuiment X-941-77--153, NASA, Goddard Space Flight Center.
- Bohse, J. R., M. Bewtra, and W. L. Barnes, 1979. Heat Capacity Mapping
 Radiometer (HCMR) Data Processing Algorithim, Calibration, and Flight
 Performance Evaluation, Tech. Memo. 80258, NASA, Goddard Space Flight
 Center.
- Jackson, T. J., T. J. Schmugge, and J. R. Wang, 1982. Passive Microwave

 Remote Sensing of Soil Moisture Under Vegetation Canopies, Water Resources

 Research, Vol. 18, pp. 1137-1142.
- Jensen, M. E. (ed), 1973. Consumptive Use of Water and Irrigation Water Requirements, ASCE, New York, NY.

- O'Neill, P., T. Jackson, B. Blanchard, R. van den Hoek, W. Gould, J. Wang, W. Glazar, and J. McMurtrey, III, 1983. The Effects of Vegetation and Soil Hydraulic Properties on Passive Microwave Sensing o. Soil Moisture:

 Data Report for the 1982 Field Experiments, NASA TM 85106.
- Rawls, W. J. and D. L. Brakensiek, 1983. A Procedure to Predict Green and Ampt Infiltration Parameters, ASAE Winter Meeting, Chicago, Illinois Soil Conservation Service, 1966. Soil Survey Queen Annes County, Maryland,
 - U.S. Government Printing Office, Washington, D.C.
- Soil Conservation Service, 1971. Soil Survey Kent County, Delaware, U.S. Government Printing Office, Washington, D.C.
- Wang, J. R., P. E. O'Neill, T. J. Jackson, and E. T. Engman, 1983.

 Multifrequency Measurements of the Effects of Soil Moisture, Soil Texture,
 and Surface Roughness, IEEE Trans. on Geoscience and Remote Sensing,

 Vol. GE-21, No. 1, pp. 44-51.

(+)

APPENDIX I AURCRAFT AND GROUND MEASUREMENTS DELMARVA SITES, 1983

LISTING CODES

= Calendar date Date = Julian day, 1983 Day Field = Field number Line = Line number Run = Run number Dirc = Flightline general direction; 0 = west to east and 1 = east to west = Crop type code, $s \in \mathbb{R}$ able 2 PCover = Percent ground cover = Crop height (cm) Hgt = Row direction, see Table 5 = Tillage code, see Table 3 Till Rough = Soil surface roughness code, see Table 4 = Soil bulk density (g/cm^3) T1 = Soil temperature at 5 cm (°C) T2 = Soil temperature at 10 cm (°C) Т3 = Soil temperature at 15 cm (°C) TIR = Field thermal infrared temperature, hand held (°C) = Volumetric soil moisture 0-5 cm (%) VSM1 VSM2 = Volumetric soil moisture 5-10 cm (%) VSM3 = Volumetric soil moisture 10-15 cm (%) SD1 = Standard deviation of volumetric soil moisture 0-5 cm (%) SD2 = Standard deviation of volumetric soil moisture 5-10 cm (%) = Standard deviation of volumetric soil moisture 10-15 cm (%) SD3 TBL = L band brightness temperature, left beam (OK) TBC = L band brightness temperature, center beam (OK) TBR = L band brightness temperature, right beam (OK) SDL = Standard deviation of brightness temperatures, left beam (OK) SDC = Standard deviation of brightness temperatures, center beam (OK) SDR = Standard deviation of brightness temperatures, right beam (°K)

ORIGINAL PAGE 13 OF POOR QUALITY

ころしょ さしろし・クトーさしでしてしてしょうしゃ マーマックーさーでしょう こうしょ・ファーをラー・ページ





ORIGINAL PAGE IS OF POOR QUALITY

```
\mathsf{Acc} \quad \Box \quad . \quad \mathsf{Aso} \quad \mathsf{acc} \quad \mathsf{
                                           งบก      อักงุนีนี้4.๑๐ •๕๒-५ •๑๗+५๗๗๚พทรกอิก+५๑๑๑๚๑๗ •५५๑๑๒๚๛๚+๑๗พฅ๚๛
                                                                                              749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 749 - 
                                                                                               THE STATE OF THE CALL OF THE COLOR OF THE CALL OF THE 
                                                                                                61583

662783

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483

311483
```



ORIGINAL PAGE 19 OF POOR QUALITY

v c œ	~ w w 4	<u> </u>	· 5 = :	56.	m 4	w 4	~ ~	∢ ₪	~ 4		v v	~-	- s	• =		~ w	•	٠ ،	S N) 4	• (7 6	9	12	•	• •	215	<u>.</u>	~
NOU	N + S F	~ m 4	ഗൈ	~ m n	i en un	9 m	~ ~	n o	- ~		v m	•	• 10		m	ი .	•		•		m		~	~	v	> ~	Œ	• 10	S.
N O J	m + + r	~ ~ ~	40	.	40	۰ م	• •	۰ م	m 4	· w		4.	• •	• •		. 0	٠	Ξ.	m 4		•	• •	•	•	٠-	٠.	٣	• =	S
⊢ Σ α	217 226 227 227	<u> </u>	252	246	242	242	263 263	261 260	264	280	562	165	172	.22	175	174 185	183	69.	231	າຕ	•	בר הבר	235	195	•	• •	202		122
⊢ ∉ ∪	223 235 235 235	23 8	258	253	248	251 251	263 263	265 264	265	285	273	•	178	•	::	180	•		•	• •	294	•	241	242	9 6	277	502	218	223
⊢ ₩ →	221 222 223 221	224	236	248	242	7.0	261 261	25.6 25.6	260	280		156	0 ·	. 74	•	192	196	£ .	234	•	•	230	206	•	25.7		193	20.5	502
v c m	<u>:</u>	9	44	4.4.	5.7	5.7	2.2	~ .	~ ~		5 0 M M	•		6.3	• •		•		•		•	•		•			•		. •
% 0 ≈	2.4.4	~ ~ ~	E e	K K 4		::	2.3	6.5	2.3	5.3		•					•		•		•	•					•		. •
s a -	2.4.4.0 6.6.0	 		η. η. φ. σ. 4		::	£ £	8 E	æ •		3.6	3.7	3°,7		5.0	5.0	5.0	, , ,	6.8	e ec	5,3	7	2.7	2.7	•	•		::	
> V I M	s		25.7						•	• •		•	• •	6.4	• •				31.2								٠,		•
	~~~ ~										-		• •	··· -															· m
> V I N	28.2 33.5 33.5																											7 [	
> v = ~	34.5 29.4 29.4	29.4	27.2	27.2	31.0	31.0	26.0	26.0	24.0	26.0		28.7	28.7	35.5	34.	29.4	4.62	\$ \$ \$ \$ \$ \$	19.2	19.2	18.3	10.5	32.1	32.1	9.91	16.6	•	2,0	
<b>⊢ ←</b> α	***	**	• • •	•••	. 2 2	27	30	2 2	98	9 6	<b>2</b> 8	6	2 2	2	• •	.5	23	2 %	35	35	•	• 6	30	30	P 6	2 6	• ;	7.7	2
<b>⊢</b> €	<u> </u>	٠٠٢	322	<b>5</b> 23	**	22	* *	2 %	2.6	7	z z	•	• •	<u>~</u>	٠.	• •	5	6 ~	2:		23	5 6	2 2	25	25	`~	r.	<u>c</u> <u>c</u>	•
<b>⊢</b> ∾	2222	22		• • 4	2 % %	92 92	• •	• •	•	• • :	::	15	15	• :	1	20	6	<u> </u>	92	9	\$	Ş		•	2 כ	32	• •	7 0	6
	2888	2 2 2	8 8	29 K	2 %	<b>92</b> 92	27	27	27	22	2 2	61	19	2 5	2	\$ 2	23	23	35	3.5	53	2	. ~	2	27	52	£.	2 2	20
<b>€</b> △	9444	94.1	***	1.48	# # # # # # # # # # # # # # # # # # #	1.48	1.48	1.88	1.48	1.48	==	=	==	* ·	**	46.1	1.34	***	**	, e	1:1	1:1	1.24	1.24	**		•	6	
αοουτ											m m	m	m m	~ ^	~	~ ~	~	~ ~	~	u ~	m	m (	٠ ١	~	~ ^	· ~	• •		~
	мене	m m m		66	n m	mm	<b>~</b> ~	w	. m c	n m		-					-			-	-	<b>-</b> -		~			• •		
203	m m	m m -	m	m m -	m	m m		m m			~ ~	~	~ ~	~ ~		~ ~	~	~ ~	~	u N		N 6	. ~	~	 	N N	~ '	۸ ۸	. ~
10-	W 4 4 4																										'		
. U O > W &	100	100	200	000		100	<b>5</b> 5	22	75	2.5	0 0	0	00	2 2	2 2	202	2	2 2	8	9 6	•	•	S	50	001	100	\$	000	100
0 × 0 €	~~~																												
	0000																												
	2112																												
_	~~~~																												
4 P D	161																												
<b>□ ∢ ⊢ W</b>																	_							_			_		
0 80 40	004 901	200	222	20:	259	- 9	20	23	2	2.2	2 2	2	<b>2</b> 9	<u> </u>	36	<b>4</b> %	9	<b>6</b> 6	8	2 7	2	ŋ :		9	,	- c	0	<u> </u>	12

### ORIGINAL PAGE IS OF POOR QUALITY

v c Œ	9 . 62 .	• • • • • • •		444004		
vau	r . r v c	104m •~0	- m - s s s n i	~ E ~ 5 8 4 4	44 · B B V *	
ros	8.625			พ พ พ จั ซั ซั	NN4 • MP 4 P	- N · O M @ 4 O 4 M 4 4 N P S P @ C ·
<b>⊢</b> Œ Œ	234	255 251 280 280	25	269 269 264 264 256	171 195 176 176 193	200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 -
<b>⊢</b> € ∪	2000	20 20 20 20 20 20 20 20 20 20 20 20 20 2	22.2	- 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	65 77 74 74 74 74	200 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 - 100 -
<b>⊢</b> E J			2003. 21			
	uu			~~~~~	-	
W C M	• • • •				* * * * * * * * * * * * * * * * * * * *	NNN
SON	• • • • •	• • • • • •	• • • • • •		• • • • • • •	4 4 4
201	25. 6.9 6.9 6.9		)	, , , , , , , , , , , , , , , , , , ,	**************************************	
> W I M		26.8 26.8 26.8			29.1 36.1 36.1 1	
~ 10 7 01	<u>.</u>	. v. v.	E E E	mmm . 4 4 1	 	# C C C M M W M M M M M M M M M M M M M M
>010	\$ 6 5 0 0 0 0	ммм	666	~~~	mmm	
> v I ~	m 4 6 8 8	22377			4 4 4 4 4 4 6 6	
<b>⊢</b> ~ a	22	. 4 8 8 4 6		200 - 640 200 - 640	222222	WW4 WW000000 .00 FE
<b>⊢</b> ∩	.0000	222222	222222	2222	5 5 5 5 5 5 5 5	
F 1	<u> </u>	. 5 2 5		22 - 22 : 52 : 52 : 52 : 52 : 52 : 52 :	222 . 355 .	
	22022	22222	200000000000000000000000000000000000000	<b>888</b> 9888	1221212	
<b>\$</b> 0	46.00		32000	46.11.1		
αοουι	~~~~	~~~~~~		nnn-nn	*******	~~~~~
<b></b>						
<b>202</b>	~~~~	, u u u u u u	~~~~~~	~~~~~	~~~~~~	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~
10-	2222	00000	, www.ooo	000000	20464400	000 x 2 2 2 2 2 0 0 0 0 0 0 0 0 0 0 0 0
7 0 0 > M &	000000	000000		000000	00000000	
C & O &	~~~~	v	1000000	mmm + NN	~~~~~~	
0-40	0 .000			000-00	000.000	00.000000000000000000000000000000000000
α⊃≵	2 25	7-0E	ve-e-			~ · · · · · · · · · · · · · · · · · · ·
-J -4 Z W	~ . ~ ~ ~		~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	~~~~~	~~~	
7 - M 7 O						****
04>						
0 < F W	52463 53163 60263 60283	60993 60993 61093 61093 61093	61363 61363 61363 61263 62263 62263 62263	62783 62783 62783 31483 51283 51283	52403 52463 52463 53463 60203 60203 60203	6699 6699 66199 66199 66199 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 6629 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 66229 662
0 8 9	154 155 156 157	1621	59959	172	1000	

## ORIGINAL PAGE IS OF POOR QUALITY

```
S C F
```



### ORIGINAL PAGE IS OF POOR QUALITY

```
\mathsf{NOU} \quad \mathsf{Sumple} \quad \mathsf{NOU} \quad \mathsf{Sumple} 
                                 THE RESIDENCE OF THE STATE OF A NAMES OF A SECOND STATE OF A SECO
                                                                             PA THE BASKS AS THE COO STREET OF THE COOL STREET AS A STREET OF THE COOL STREET OF THE C
```



# ORIGINAL PAGE IS OF POOR QUALITY

v 0 6		• • •	• •	•	• •	2 6	=	n •	e v	`~	<b>*</b> 2	2	• =	: :	* !	ť e	1	•	• •	13	5	<u>.</u>	Ξ.	ج ه	•	< •	n <b>o</b>	æ	٠.	•	۳.	• «	ø
v e v	80 m m	٠.	==	2	٠2.	<u> </u>	<b>:</b> •	=	==	2 2	E 0	2	5.5	2 2	2:	- =	=	9.5	2.1	21	ñ	£ 2	20	- 0	c	٥ '	E 0	•	• 4	n <b>~</b>	٥,	7 V	m
ده ۷	<b>e</b> gn;	: • 2	<b>:</b> :	:=;	S=	2 2	2	2 2	2	200	<u> </u>	15	= =	. •	=:	2 =	~	<b>*</b> :	^ c	23	2	• :	5	3 5	: ≃	<b>∴</b> ′	^ O	0	• •	10	2	n w	•
<b>⊢ œ œ</b>	197 202 260	• • •		163	513	23.4	216	7	250	245	24.7	248	252	548	255	9 5	276	26.2	262	243	234	\$ \$	260	186	216	239	261	227		180	26	181	190
<b>⊢</b> ± ∪	230 230 278		173	176	201	203	236	502	250	230	232	244	243	248	239	ć K	252	257	22.	221	225	234 254	255	666	208	213		202		183	981	2 E T	187
<b>⊢ ∉</b> ⊃	231	. 25	150	69	00	<b>\$</b> 02.0	536	107	4	5 4 6	949	23	25.56	3 5	25	s e	940	36.	e &	245	540	245 255	265	٠ <u>و</u>	205	255	175	=	• •	5	06.	2 2	100
NCM		<i>.</i>	•			•			~ ~				•		•						•		•			•							
<b>⋄</b>			•	2	0 r.	۰ ۰			e e	:																							•
					0.00		<u></u>	e e :	<b>.</b>	}			•													. :		~	ĸ -	::	; ·		
vc-			2	7	<b>Z</b> =	~ ~	, × .	• •																		ſ	v ~	~			~ `		
> 0 % M	37.8 37.8 23.4	• • •	•	• •	• •	• •	•	• •			• •	•	•	• •	•	• •	•	•	• •	•	•	• •	•	•	• •	• ;	78.5	28.6			• ;		44.3
> V I N	•••	• • •		33.	4 2	24.1 2.15	23.5	• •	26.7		•	•	•		•		•	•	• •	• •	•		•	•	• •	•	34.3	34.3	•		•		•
> v I	37.2 37.2 15.3		. •			¥ =			• •					٠.	•			•	•				•	•		•	57.1	57.1	F • 63	***		. • •	36.4
		:22					_								•			•			•				· E					 			
<b>⊢</b> €	F F E 6	• •	•	• • •	P (	٠ م	• • •		 						•										· <u>•</u>	•	• •	•	_			D &	
<b>⊢</b> ~				•	• •	• ŭ	Σ	• •	~ ^						•									•		•		•	•	• •	• ;		=
	22	2	200	: 5 :	2 2								•		•		•	•	• •				•	٠,	. <u>.</u>	5	2 2	<u>•</u>	0 d	: 5	<u>.</u>	72	53
<b>.</b> .	957		ř.	*	4.	4.5		• •	* *		•							•	• •						. :			•					•
a 0 3 9 I			~~	. ~ :	~~	~ ~	. ~ .		~ ~	•															. –	<del></del> -		_					_
							. <i>.</i>						•		•									•	•	n	7 17	~	m -	. ^	<b>m</b> r	7 ~	-
<b>«</b> 0 »	~~~	ہ ہ	~ ^	. N	N N	~ ^	, <b>~</b> f	· ~	~ ^	. •	• •	•	•	•	•	• •	•	•	• •	•	•	• •	•	• ^	۱ ۸	~ 1	v N	~	~ ^	) N	~ 1	· ~	~
10-	nno.	n 40 e	• :	: = :	2 %	% <b>?</b>	2 :	• ;	3 3	; .	•	• •	•	• •	•	•	•	•	•	• •	•	• •	•	•		~ 1		~	7	2	2 :	<u> </u>	-2
.uo>L=	• • • •	22		223	2 2	° ,	2	;	\$ 5	:	::	0	900		=	0 0 0 1	00	60		7.00		9 0	0	0	. 6	200	0 0	000	000	6	00.	0 0	00
U @ C &	<b>~~~</b>	~ ~	~ ~	~	~ ~	~ ^	· ~ ·	~ ~	~ ^		•		•	• •	•	•	• •	•	•		•	• •	•	•	-	(	<b>~</b> ~	~	~ ^	۰ ~	۸,	۰ ~	~
c <b>-</b> α ∪		• •	0	•	• •	0 0		0	0 0	•	• •	•	•	•	•	- •	•	•	0 0	•	3		•	e -	ء -	•	0	•	• •	<b>,</b> 0	، ن	9 0	0
425	- ~ - ^																																
<b>→ 2 w</b>	000																																
<b>~~</b> ₩JC	====	:::	==	<b>:</b>	-:	<b>=</b> =	1 = 1	::	-:	2	<u> </u>	2	2 3	2	5	<u> </u>	2	<u> </u>	<u> </u>	2	-	2 z	2		<u> </u>	<b>2</b> :		=	= =	. <u>.</u>	= :	≗ ≟	=
04>	222																																
0 <b>4</b> F W	31443	53103	60243		61083	61 363	41583	62283	62783	60203	40203				61063	613	61313	61503		6229	42283	62263	62783	62783		51203	52483	52483	53143	60203	60203	\$ 0 0 V	£0007
0	***		25	2	11	=======================================	2	12f 326		, <u>2</u>	22	25	2		315		335	2		3.5	340	73	3	***	i	7		35	33	121	32	, , ,	15.7

## ORIGINAL PAGE IS OF POOR QUALITY

vΩα	& N P &	w ~ o o		o- 20 ao ao	0 ~ 0 M ±		6 1 1 1 2 2 4 2	• <b></b>	<b>6046066008</b>
ທລບ	10 01 m 4								<b></b>
V/30									<b>~ m 4 m m m 0 * m 4 m w</b>
د د	F 0 V 4 I	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	- 444 .	51 71	4776	2 5 5 6 60 E	2.2.% R 8 5 7	15.53.5	0 < 4 > < 4 < 4 < 4 < 4 < 4 < 4 < 4 < 4 <
<b>⊢</b> ∞ α	189 194 221 209	204	216 218 218 234	240	9,09,2	256	213 215 215 263 263	223 223 225 255 258 258	254 265 265 265 277 277 281 198
<b>⊢ د</b> د	202 208 208	202	222	242	263	250 250 274 276	27.3 22.3 27.3 27.3	25.5 25.5 25.5 25.5 25.5 25.5	2255 2255 2255 2255 2255 2255 2255 225
⊢æ⊐									253 253 263 263 263 273 273 268 268 205
s o e	• • • •			~~~~~					******
SON					• • • • •		• • • • • •	· • • • • • •	• • • • • • • • • •
201	6444						M444777		*********
	8666	0 ~ O O O		4 4 6 6 6 6	~~~~				
> W I M				44.55	52.57	5.5.5.5	0000	20.	44600000000
> v <b>z</b> v	4 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0			• • • •	• • • •	• • • • •	• • • • • •	• • • • • • •	• • • • • • • • • • •
> 0 I ~	0.444		25.7.7.6 19.0	. v. v. v.	22.1.2.2	9.00	U E E E O C O	* ~ ~ ~ ~ ~ ~	20000000000000000000000000000000000000
<b>⊢ ⊢ α</b>		• • • • •	0000	• • • •	• • • • •				
<b>⊢</b> 6	E 4 4 4 6						•0000777	. <b></b>	•••••••
<b>⊢</b> ∾			• \$ \$ \$ ·						
<b>-</b> -	20000						•ທທທວວວ		• • • • • • • • • • • • • • • • • • • •
			000004						
<b>£</b> 0								4004440	200000000000000000000000000000000000000
@ 0 : O I				~~~~				~~~~~~	~~~~~~~~~
	<b></b>	10000							
a C 3									~~~~~~~~~~
IO⊢									
700>m4			100	ርኢኢኢ	5252	2 1 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	2000 W W W		
0404	~~~~		10000	ս և ոս ոս դ	ւտոտու			•••	
0 - 6 0	00000		• • • • •	0000	000-	0000		• = = = = = = = = = = = = = = = = = = =	
α⊃Ζ	~~~~	- n - n n	- NO	- 10 - 10 -	- C E -	~~~~	1-2E-2E	•	M - M B - M B - M B
7 ~ S M	~~~~			• • • • •	****	****	*****		• • • • • • • • • •
F - B - O	5555	2222	2225	11111	::::::	2222			
0 <b>4</b> >	2011	166 173 173	178	153	191	491	173 173 173 178 178	160	1001 1004 1004 1004 1004 1004 1004 1004
0 <b>4</b> F w	90000	22.25	27.2	8 6 6	665 F	565	22222	000000000000000000000000000000000000000	6 1 1 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
0 20 41	359 360 361	364	369	375 375 476 876	376 376 378 379	381		395 395 395 395 395	00000000000000000000000000000000000000



## ORIGINAL PAGE (9 OF POOR QUALITY





## ORIGINAL PAGE 19 OF POOR QUALITY

 $\begin{array}{c} \text{ } \\ \text$ ALDERDED TO THE TOTAL OF THE TO ቁቁቁቁቁቁቁቁቁቁቁቁቁ የመመመው የመ 



# ORIGINAL PAGE IS OF POOR QUALITY

<b>∿</b> ເ) Œ	===	• •	•	• (	V 4	~	0	m	• 10	• (	~ ^	, RU	~	•	~ 4	~	n	~	='	, c	·	C	m (		-	•	\ L	, RU	•	S.	- (	) CO	_	59	Œ	۵ ۵	n en	¢	4 ~
y a u	r~ cc	٠.	ις:	۸.	- ^	·	<b>(</b>	m -	٠ ~	• (	<b>~</b> -	- ،	~	<b>m</b>	۰ م	۸ د		m	m .	ى ب	13	е	•	<b>-</b> u	۱.	Œ (	<b>&gt;</b>	•	~	•	Ξ,	۰ م	. 0	'n	е	<b>o</b> r	۰ ۸	o	<b>4</b> ~
د ه <b>۸</b>	: °	• •		m 1	n <b>4</b>	-	•	m -	• •	• .	• •	_	•	•	r	, ec	~	=	m ;	3 '	• •	-	in 4	۳ م	'n	2	- 2	~	m	•	œ S	<u> </u>	m	59	m ·	<b>60</b> 0	D ~	~	<b>60</b>
⊢œœ	281 27A	• •	•	•;	276	295	233	276	287	•	E 00	265	569	992	275	289	2AA	260	246	777	272	274	273	275	275	270	27.	273	278	276	285	285	289	261	263	281	279	284	283
<b>⊢</b> ⊈ ∪	281 288	• •	192	566	270	300	247	252	262	• [	27.	270	273	272	242	291	162	264	261	200	292	569	262	0 / V	275	268	240	270	274	272	243	283	277	288	284	275	281	278	283
F & J	275	• •	248	254	- 40	287	540	235	283	• (	262	265	262	992	275	28.	286	241	259		271	267	272	272	274	268	2 2	274	275	274	0 H C	281	284	252	280	275	276	282	278
NEM	9.0		9.9	0.			2.1		3.0	4.	• •	•	•	• (	• •	1.5	1.5	2.3	N 0		•	•	•	•		•	• •	•	•	•	•		. •	•	•	•	• •	•	
8 C C	• •	• •	•	•	• •	•	•	•	• •	•	٠.	•	•	•	• •	•	•	•	•	• •	•	•	•	• •	• •	٠	• •	•	•	•	•			•	•	•	٠.	•	• •
<b>5</b> C -	# # ·	e ¢.	1.6	٠	• •	.5	•			•			•	e .		7.0	1.6	2.1	2.7	0	•	•	•	•	•	•	• •	•	•	•	•		. •	•	•	•	٠.	•	
> vi z m	5.7											•	•	•			•	•	•		•	•	•			•	• •	•	•	•	•		•	•	•	•	• •	•	
> v z v	• •		•	•	٠.		•			•	٠.	•	•	•	• •		•	•	•		•	•	•			•		•			•				•	•			
> v/ Z ~	4 4 9	16.0	15.9	12.3	12.0	A .	9.0		5.6	17.6	13.3	13.3	12.1	15.1		9.5	\$. 5	7.9	17.9	9 60	•	•	•		•	•		•	•	•	•		•	•	•	•		•	
<b>⊢ ⊢</b> □	• •		•	•		•	•		•	•		•	•	•				•	•		•	•				•		•	•	•	•		•	•		•		•	
<b>⊢</b> €				•			•			٠	٠.	•	•	•	• •		•	•	•		•		•		•	•		•	•		. ,		•	•	•	•		•	
- ~			•	•		•	•		•	•	٠.	•	•	•	• •	•	•	•	•		•	•	•		•	•		•	•	•	• •			•	•	•		•	
	28 28		•	• 4	£ 5	۶.	•	. 8	88	•	• •	•	•	•	• •	. 5	20	<b>%</b>	<b>*</b> u	2 %	•	•	•	• •	•	•	• •	•	•	•	• •	• •	•	•	•	•	• •	•	• •
α =	1.45	1.34	1.34	1.34	1.34	1.34	64.	5 4	1.49	1.25	1.26	1.26	1.26	e .	1.26	1.26	1.26	1.39	1.39	1.39	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	200	1.20	1.20	1.20	1,20	1.20	1.20	1.20	200
20001	~~	• •	٣	m r	) m	, –	<b>m</b> 1	2	9	~ (	٠.	~	۸ (	~ (	٠,	. ~	۰	۸,	N C	٠		_						-	_				-	_	-	<b></b>	. –	٦.	
			-	<b>-</b>	-	~	۰.		-	~ -		~		٠.		-	-	<b>~</b>	<b>-</b> -	-	_	-	<b>-</b>		_		-	-	-	٦.	-		-	-	٦.	<b></b>		٦.	
αφΒ	m m -		-			· ~	٠,		-			_		٠,		-	_			٠,	•	4	• •	• •	•	•	•	4	•	•	• •	•	•	•	٠.	4 4	•	4 .	• •
I છ.⊢	22	2 2	20	8 4	7 7	8	6	175	125	0 0	s w	ស	in i	n	20	15	15	20	0. F	300	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248	248
0 O > 16 at	000	30	0	<b>9</b> 9	9 9	2	Ç (	9 6	100	0 0	<b>.</b>	ır.	so.	n :	9 0	15	15	20	50	90	100	100	100	000	100	000	000	100	100	200	97.		١	100	007	001	200	100	100
υαοα	• • •	v ~	~	۸ ،	<b>N</b>	~	N I	٠ ۸	~		- m	e	m e	ا ت	. C	n	٣	<b>6</b>	m (	n m	-	-		- ~	-			-	-	<b>-</b> •		• -		-4 (	~ ⋅		. –	٠.	
0-40	• -	• •			-	. 0	۰.	- 0	-	• •	<b>&gt;</b> 0	-	۰ .	- •	-	0		0	- 0	-	•	0	0	•	0	0 9	•	0	0	0	<b>o</b> c	•	0	۰ ۵	0	00	, 0	0	0
<b>α⊃</b> ≥	- ~	• •	~	- د	٠ ٨	-	، -	<b>~</b>	~	• -		N	(	٠.	- ~	~	8	- 1	٧-	٠ ~		-			-		• ~	-	~		- ۳	. –	-	<b></b> .	~ .			۰.	
_	N N	• •	S.	<b>ن.</b> ب	ח ה	S.	ហេដ	n n	· C	• 4	רעי	ĸ	S (	<b>n</b> (	n u	'n	'n	<b>1</b>	n u	n un	-	~	ო -	٠.	m	m -	• ~	m	~	m .	٠,	•	-	~ 1	m·	- ^	1 M	~ (	<b>v</b> M
r-u	22																																						
<b>c ∢</b> ≻	178		-		٠, -			- ~	_		-	~	⊸ .	٠		~	_						~ -	-	_		• ~	-				• ~	_	٠.	٠		••	~ -	
04FW	62783	60203	60983	61083	61383	61583	62283	62783	62783	53183	60983	60983	61083	61063	61383	61583	61583	62283	62283	62783	51283	51283	51283	52483	52483	60283	60983	60983	61083	61083	61383	61383	61583	61583	61583	662293	62283	62783	62783
0 8 9	513	217	515	516	518	519	520	125	523	524	526	527	528	200	531	532	533	\$ 10 10 10 10 10 10 10 10 10 10 10 10 10 1	0 P	537	538	539	940	245	543	544	1 9	241	248	549	200	555	553	554	555	556	558	559	561



# APPENDIX II CLIMATOLOGICAL DATA - DELMARVA PENINSULA May and June 1983

### LISTING CODES

DAY	=	Julian Day, 1983
R1	=	Daily rainfall, Wye Institute, MD (cm)
R2	=	Daily rainfall, Centerville, MD (cm)
R3	=	Daily rainfall, Denton, MD (cm)
R4	=	Daily rainfall, Royal Oak, MD (cm)
R5	=	Daily rainfall, Dover, DE (cm)
R6	=	Daily rainfall, Milford, DE (cm)
R7	=	Daily rainfall, Willow Grove, DE (cm)
R8	=	Daily rainfall, Darling, DE (cm)
EVAP	=	Daily pan evaporation (cm)
TAIR	=	Mean daily air temperature (°C)
TDEW	=	Mean daily dew point temperature (°C)
WIND	=	Daily wind (km/day)
RAD	=	Solar radiation (Langleys)
PET	=	Penman daily potential evapotranspiration (cm)

PRECEDING PAGE BLANK NOT FILMED

# ORIGINAL PAGE IS OF POOR QUALITY

_		_		_						_				۸.	۰.	~	_	_				•	æ									- 0		. ^				_		_	<u> </u>	<u>۰</u>	_	an i	r.		<b>.</b>		c •		2 (	• 4	۰ د	<b>n</b> -	٠ .	2 (	•
RAD	í	2	527	676	4			0 0		0	68	99	58	50%	3	6.6	65(	32	316	16.	12	555	47	70	4	ď	Ċ	, ă		4	5 8	7 4	2	י ה	9 4	5	200	63	9	65	9	65	63	9	0	9	65	n c	ñ .	7 :	•	0 6	2 4	603	2 6	- 7	0
ON I B		26.2	747	193	200	0 0	P 10 0	0 0	500	•	161	127	131	166	429	264	170	305	259	139	197	154	270	151	22.	150	101		130	162	200	9 6	946	250	121	100	127	100	263	151	189	124	66	108	139	141	120	21.	2.	2 6	212	200	E d	930		97.0	1
TOEW		ç.	0.9	A . I		- [		0.0		2•3	~;	7.5	13.9	17.7	10.6	2.4	7.3	6.6	17.0	18.4	17.4	18.	12.1		4		0 0		13.4									14.	10.0	11.7	14.9	17.0	10.4	19.2	8.0	19.5	19.1	× 6	F 02	102	. H.		E • 0	0.0	•	13.4	•
1419		15.0	H . H	4.4		1 .			* ·	13.1	12.9	15.1	10.4	21.5	12.5	30.8	14.0	15.5	19.7	19.A	18.6	21.A	18.3	17.1	17.5	4	9.4	201	20.1	1 0 0			7	, C	0.00	22.3	21.1	200	17.9	17.6	21.8	24.0	25.52	25.1	24°A	25.1	\$ 100 C	0.0	23.5	x .	20.7	0 1 2	٠٠٥٠	9.5.0	0.45	9422	
PFT		0.40	0.43	45.0		0 1	9 4 4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	00.0	6.0	0.53	0.54	0.51	9.0	0.39	0.04	0.54	0 4 0	. 31	6,	000	0.06	0	0.44	0.57	8.0		0.0	-	21.0			0.63	9 6	200		700	0	05.0	0.57	0.51	0.58	0.57	0.53	0.52	0.56	0.5A	0 55 1		92.0	61.0	0 °0	E .	9.0	95.0	2/.0	200	50.0
FVAP		٧.	S	~	. 0	•	U o	τ.	Ξ.	S.	Œ	•	40	۲,	0			۳,	9			. "		. •		•	٠,٠				٠,			''	ř	7,			: ~		٠.	٠.	w.	٧.	۳.	٧.	٠.	- '		٠.	٠,	- '	Ξ,	 6	╗,	٠,	7
EPAN		č	ŝ	-	. 0	٠.		ı,	Œ	Ś	Œ	0.69	•	S	-5.11	6,0	0.79	^		-0.39				•	ď	Ò	5 4	ċ.	000	Ú	ם פ	, i	•		2 1	٠.	•	v	9		0.98	α	ĕ	0	0 . R.	c	ر به	٠.	•	Ç	E 1	٠.	0.78	0.81	91.1	9.0	<b>?</b>
вα			•	•	•	•	•			•	•	•	•	•	•					•	•	٠,		٠,	٠	•	•	٠,	٠,		•	•	•	•	•	•				•	٠.	c.	۰.	٤.	ç,	٠,	Ç	٠,	`.	•	٠,	٠,	٠,	00.00	٠, ۱	•	•
7 9			•	•	•	•	•		•	•	•	•	•	•	•				•	•				•		•		•	•		•		•	•		•	•	•				•	•	•	•	•	•	•			•	•	•	0.00	•	•	•
98		1.07	00.0			00.0	00.0	0.08	0.0	00.0	00.0	0.00	00.0	0.08	3.91			0.00	9.5		4.	40.0			4			•	9	0.10			00.0	00.0		000		0.4.0	00.0	000	0.00	0.00	00.0	00.0	0.00	0.00	0.00	00.0	0.56	0.30	8.66	0.05	0.00	00.0	00.0	0.00	00.0
RS		1.57	00.00		900	00.0	0.00	0.0	0.00	00.0	00.0	0.00	00.0	1.60	5.56			00.0		1 7 3	4							0.00	,			0.13	00.0	00.0	14.0	000		0.00		00.0	00.0	0.00	00.0	00.0	0.00	00.0	00.0	00.0	0.46	0.48	9.68	0.38	0.00	0.00	0.00	00.0	0.00
œ.		1.09	00.00		50.0	00.0	00.0	0.28	00.0	00.00	00.0	00.0	00.0	6.5	7.64				9	75		70.0		3	•	0 0	6.50	00.0	70.4	1.35	9.	0.46	00.0	00.00	1.03	00.00		•		00.0	00.0	00.0	00.0	00.0	00.0	0.00	00.00	0.00	00.0	6.83	4.70	0.00	000	00.0	0000	00.0	00.0
ва		1.70	00.0		20.0	00.0	000	0.13	0.00	00.0	00.0	00.0	00.0	2,36	96.4				4		4			•			1.73	00.0	0.58	5,0	90.6	02.0	60.0	0.00	60.0	00.0	9	•	•		00.0	00.0	00.0	00.0	00.0	0.00	0.08	0.33	3,30	5.31	0.33	0.00	00.0	0.00	0.00	0.00	0.00
28		7 - 7	0.0		•	•	•	0.	0.0	••	0.0	0	0								1	•		•	•	•	2	•	-	-	•				-	•	•	-			0	•	•	0	•	•	•	•	•	_	m	•	•	0.00	•	•	ં
a		0.63	0		000	0.0	0.1.0	0.0	0.00	00.0	00.0	00.0	00.00	1	7 - 7	,	•	-		000	2,00	1			•	2.10	14.0	00.0	20.0	0.13	0.0	0.13	0	1.52	0.13	0.0	35.0			9	0	00.0	00.0	00.00	0.00	00.0	0.0	0.00	0.25	3,30	0.51	0.00	0.00	0.00	0.00	0.00	0.0
PAC		124	120	1	971	121	128	129	130	131	132	=	34	136	2 5	1		200	104		1			* .	0.	0	147	148	140	150	151	152	153	154	155	156	157	E 4	<u> </u>	2	16.2	163	164	165	166	167	168	169	170	171	172	173	174	175	1,6	177	178
SHO		_	^	٦,	٦,	•	S	•	~	æ	0		:=	: :	. ~	? .		1 1	2 :	_ 9	9.	2 6	? ?	1,0	2	2	<b>*</b>	52	\$	27	8	2	9	3	35	E :	<b>#</b> 4	5	5 2	÷ =	9 6	9	7	42	<b>*</b> 3	;	45	9	-	•	<b>6</b>	20	51	25	53	\$	55

